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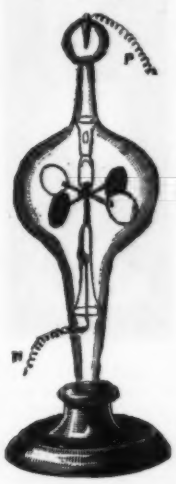
MOLECULAR PHYSICS IN HIGH VACUA.*

By WILLIAM CROOKES, F.R.S.

WHEN I was asked, a month or two ago, to illustrate in this theater some of my recent researches on molecular physics in high vacua, I exclaimed, "How is it possible to bring such a subject worthily before a Royal Institution audience when none of the experiments can be seen more than three feet off?" If to-night I am fortunate enough to

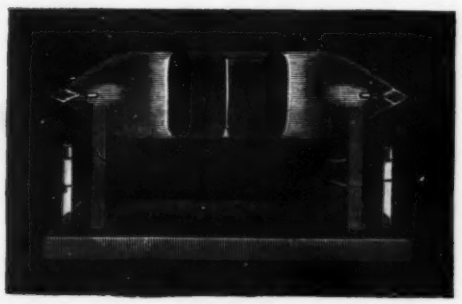
FIG. 1.



show all the experiments to those who are not far distant, and if I succeed in making most of them visible at the far end of the theater, such a success will be entirely due to the great kindness of your late secretary, Mr. Spottiswoode, who has placed at my disposal his magnificent induction coil—not only for this lecture, but for some weeks past in my own laboratory—thus enabling me to prepare apparatus and vacuum tubes on a scale so large as to relieve me of all anxiety so far as the experimental illustrations are concerned.

Before describing the special researches in molecular physics which I propose to illustrate this evening, it is necessary to give a brief outline of one small department of the modern theory of the constitution of gases. It is not easy to make clear the kinetic theory, but I will try to simplify it in this way: Imagine that I have in a large box a swarm of bees, each bee independent of its fellow, flying about in all manner of directions and with very different velocities. The bees are so crowded that they can only fly a very short distance without coming into contact with one another or with the sides of the box. As they are constantly in collision, so they rebound from each other with altered velocities and in different directions, and when these collisions take place against the sides of the box pressure is produced. If I take some of the bees out of the box, the distance which each individual bee will be able to fly before it comes into contact with its neighbor will be greater than when the box was full of bees, and if I remove a great many of the bees I increase to a considerable extent the average distance that each can fly without a collision. This distance

FIG. 2.



I will call the bee's *mean free path*. When the bees are numerous the mean free path is very short; when the bees are few the mean free path will be longer, the length being inversely proportional to the number of bees present. Let us now imagine a loose diaphragm to be introduced in the center of the box, so as to divide the number of bees equally. The same number of bees being on each side, the impacts on the diaphragm will be equal; and the mean speed of the bees being the same, the pressure will be identical on each side of the diaphragm, and it will not move.

Let me now warm one side of this division so as to let it communicate extra energy to a bee when it touches it. As before, a bee will strike the diaphragm with its normal mean velocity, but will be driven back with extra velocity, the reaction producing an increase of pressure on the diaphragm. It will be found, however, that although the diaphragm is free to move, the extra strength of the recoil on the warm side does not produce any motion. This at first sight seems contrary to the law of action and reaction being equal. The explanation is not difficult to understand. The bees which fly away from the diaphragm have drawn energy from it, and therefore move quicker than those which are coming towards it; they beat back the crowd to a greater distance and keep a greater number from striking the diaphragm. Near to the heated side of the diaphragm the density is less than the average, while beyond the free path the density is above the average, and this greater crowding extends to all other parts of the box. Thus it happens that the extra energy of the impacts against the warm side of the diaphragm is exactly compensated by the increased number of impacts on the cool side. In spite, therefore, of the increased activity communicated to a portion of the bees, the pressure on the two sides of the diaphragm will remain the same. This represents what occurs when the extent of the box containing the bees is so great, compared with the mean free path, that the abrupt change in the velocities of those bees which rebound from the walls of the box produces only an insensible influence on the motions of bees at so great a distance as the diaphragm.

I will next ask you to imagine that I am gradually removing bees from our box, still keeping the diaphragm warm on one side. The bees getting fewer the collisions will become less frequent, and the distance each bee can fly before striking its neighbor will get longer and longer, and the crowding in front of them will grow less and less. The compensation will also diminish, and the warmed side of the diaphragm will have a tendency to be beaten back. A point will at last be reached on the warm side, when the mean free path of the bees will be long enough to admit of their dashing right across from the diaphragm to the side of the box, without meeting more than a certain number of in-coming

FIG. 3.

bees in their flight. In this case the bees will no longer fly quite in the same direction as before. They will now fly less sideways, and more forwards and backwards between the heated face of the diaphragm and the opposed wall of the box. Because of this preponderating motion, and also because they will thereby less effectually keep back bees crowding in from the sides, there will now be a greater proportionate pressure both on the hot face of the diaphragm and on that part of the box which is in front of it. Hence the pressure on the hot side will now exceed that on the cool side of the diaphragm, which will consequently have a backward movement communicated to it.

I may diminish the size of the bees as much as I like, and by correspondingly increasing their number the mean free path will remain the same. Instead of bees let me call them molecules, and instead of having a few hundreds or thousands in the box let me have millions and billions and trillions; and if we also diminish the mean free path to a considerable extent, we get a rough outline of the kinetic theory of gases. (I may just mention that the mean free path of the molecules in air, at the ordinary pressure, is the ten-thousandth of a millimeter.)

Three years ago I had the honor of bringing before you the results of some researches on the radiometer. Let me now take up the subject where I then left off. I have here two radiometers which have been rotating before you under the influence of a strong light shining upon them.

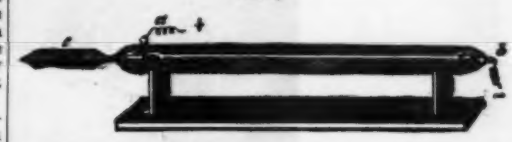
The explanation of the movement of the radiometer is this—the light, or the total bundle of rays included in the term "light," falling upon the blackened side of the vanes, becomes absorbed, and thereby raises the temperature of the black side: this causes extra excitement of the air molecules which come in contact with it, and pressure is produced, causing the fly of the radiometer to turn round.

I have long believed that a well-known appearance observed in vacuum tubes is closely related to the phenomena of the mean free path of the molecules. When the negative pole is examined while the discharge from an induction-coil is passing through an exhausted tube, a dark space is seen to surround it. This dark space is found to increase and diminish as the vacuum is varied, in the same way that the ideal layer of molecular pressure in the radiometer increases and diminishes. As the one is perceived by the mind's eye to get greater, so the other is seen by the bodily eye to increase in size. If the vacuum is insufficient to permit the radiometer to turn, the passage of electricity shows that the "dark space" has shrunk to small dimensions. It is a natural inference that the dark space is the mean free path of the molecules of the residual gas.

The radiometer which has just been turning under the influence of the lime-light is not of the ordinary kind. Fig. 1 will explain its construction.

It is similar to an ordinary radiometer, with aluminum

FIG. 4.



disks for vanes, each disk coated on one side with a film of mica. The fly is supported by a hard steel instead of glass cup, and the needle point on which it works is connected by means of a wire with a platinum terminal sealed into the glass. At the top of the radiometer bulb a second terminal is sealed in. The radiometer can therefore be connected with an induction coil, the movable fly being made the negative pole.

As soon as the pressure is reduced to a few millims. of mercury, a halo of velvety violet light forms on the metallic side of the vanes, the mica side remaining dark. As the pressure diminishes, a dark space is seen to separate the violet halo from the metal. At a pressure of half a millim. this dark space extends to the glass, and positive rotation commences. On continuing the exhaustion the dark space further widens out and appears to flatten itself against the glass, when the rotation becomes very rapid.

You perceive a dark space behind each vane and moving round with it. In the first experiment, radiation from the lime light falling on the metallic sides of the vanes, produced a layer of molecular pressure which drove the fly round; so here the induction current has produced molecular excitement at the surface of the vanes forming the negative pole, extending up to the side of the glass.

When the negative pole is in rapid rotation it is not easy to see this dark space, so I have arranged a tube in which the dark space will be visible to all present. The tube, as you will see by the diagram (Fig. 2), has a pole in the center in the form of a metal disk, and other poles at each end. The center pole is made negative, and the two end poles connected together are made the positive terminal. The dark space will be in the center. When the exhaustion is not very great the dark space extends only a little distance on each side of the negative pole in the center. When the exhaustion is very good, as it is in the tube before you, and I turn on the coil, the dark space is seen to extend for about two inches on each side of the pole.

FIG. 5.

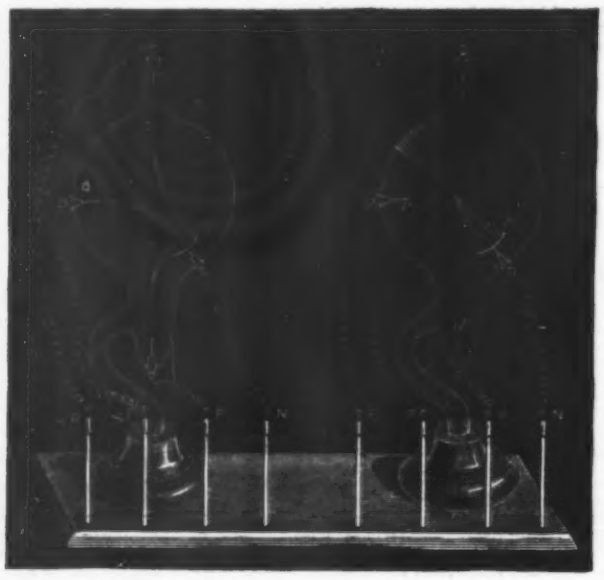
Here, then, we see the induction spark actually illuminating the lines of molecular pressure caused by the excitement of the negative pole. The thickness of this dark space—nearly two inches—is the measure of the mean free path between successive collisions of the molecules of the residual gas. The extra velocity with which the negatively electrified molecules rebound from the excited pole keeps back the more slowly moving molecules which are advancing towards that pole. The conflict occurs at the boundary of

*A short-hand report of a lecture delivered at the Royal Institution, on Friday, April 4, 1879.

the dark space, where the luminous margin bears witness to the energy of the discharge.

I will endeavor to throw on the screen an illustration of this dark space. A stream of water falls from a small jet on to a horizontal plate of glass. The water spreads over the plate and forms a thin film. The jet of water in the center, from the velocity of its fall, drives the film of water before it on all sides, raising it into a ring shaped heap. As I diminish the force of the jet the ring contracts; this is equivalent to the exhaustion getting less. When I increase the force of water the ring expands in size, the effect being analogous to an increase of exhaustion in my tubes. The extra velocity of the falling particles of water drive the incoming particles of water before them, and raises a ridge

FIG. 6.



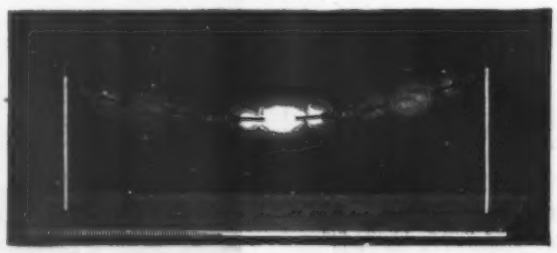
round the side which exactly represents the luminous halo to the dark space to be seen in this tube.

If, instead of a flat disk, a metal cup is used for the negative pole, the successive appearances on exhausting the tube are somewhat different. The velvety violet halo forms over each side of the cup. On increasing the exhaustion the dark space widens out, retaining almost exactly the shape of the cup. The bright margin of the dark space becomes concentrated at the concave side of the cup to a luminous focus, and widens out at the convex side. When the dark space is very much larger than the cup, its outline forms an irregular ellipsoid drawn in towards the focal point. Inside the luminous boundary a dark violet light can be seen converging to a focus, and, as the rays diverge on the other side of the focus, spreading beyond the margin of the dark space; the whole appearance being strikingly similar to the rays of the sun reflected from a concave mirror through a foggy atmosphere. This proves a somewhat important point; it shows that the molecules thrown off the excited negative pole leave it in a direction almost normal to the surface.

I can illustrate this property of the molecular rays by an experiment. This diagram (Fig. 3) is a representation of the tube which is before you. It contains, as a negative pole, a hemi-cylinder (*a*) of polished aluminum. This is connected with a fine copper wire, *b*, ending at the platinum terminal, *c*. At the upper end of the tube is another terminal, *d*. The induction coil is connected so that the hemi-cylinder is negative and the upper pole positive, and when exhausted to a sufficient extent, as is the case with this tube, the projection of the molecular rays to a focus is very beautifully shown. The rays are driven from the hemi-cylinder in a direction normal to its surface; they come to a focus and then diverge, tracing their path in brilliant green phosphorescence on the surface of the glass.

You will notice that the rays which project from the negative pole and cross in the center have a bright green appearance; that color is entirely due to the phosphorescence of the glass. At a very high exhaustion the phenomena noticed in ordinary vacuum tubes when the induction spark passes through them—an appearance of cloudy luminosity and of stratifications—disappear entirely. No cloud or fog whatever is seen in the body of the tube, and with such a vacuum

FIG. 7.



as I am working with in these experiments—about a millionth part of an atmosphere—the inner surface of the glass glows with a rich green phosphorescence, the intensity of color varying with the perfection of the vacuum. It scarcely begins to show much before the 800,000th of an atmosphere. At about a millionth of an atmosphere the phosphorescence is very strong, and after that it begins to diminish until there are not enough molecules left to allow the spark to pass.*

I have here a tube which will serve to illustrate the de-

* 1·0 millionth of an atmosphere — 0·00076 millim.
1315·789 millionths of an atmosphere — 1·0 millim.
1,000,000·0 " " " — 760·0 millims.
" " " " — 1 atmosphere.

pendence of the green phosphorescence of the glass on the degree of perfection of the vacuum (Fig. 4). The two poles are at *a* and *b*, and at the end (*c*) is a small supplementary tube connected with the other by a narrow aperture, and containing solid caustic potash. The tube has been exhausted to a very high point, and the potash heated so as to drive off moisture and deteriorate the vacuum. Exhaustion has then been re-commenced, and the alternate heating and exhaustion have been repeated until the tube has been brought to the state in which it now appears before you. When the induction spark is first turned on nothing is visible —the vacuum is so high that the tube is non-conducting. I now warm the potash slightly, and liberate a trace of aqueous vapor. Instantly conduction commences and the green phosphorescence flashes out along the length of the tube. I continue the heat, so as to drive off more gas from the potash. The green gets fainter, and now a wave of cloudy luminosity sweeps over the tube, and stratifications appear. These rapidly get narrower, until the spark passes along the tube in the form of a narrow purple line. I take the lamp away and allow the potash to cool; as it cools the aqueous vapor, which the heat had driven off, is reabsorbed. The purple line broadens out and breaks up into fine stratifications; these get wider and travel towards the potash tube. Now a wave of green light appears on the glass at the other end, sweeping on and driving the last pale stratification into the potash; and now the tube glows over its whole length with the green phosphorescence. Would time allow I might keep it before you, and show the green growing fainter and the vacuum becoming non-conducting; but time is required for the absorption of the last traces of vapor by the potash, and I must pass on to the next subject.

This green phosphorescence is a subject that has much occupied my thoughts, and I have striven to ascertain some of the laws governing its occurrence. I soon perceived that the phosphorescence was not in the body of the tube itself, but was entirely on the surface of the glass. Another peculiarity of the rays producing this green phosphorescence, is that they will not turn a corner in the slightest degree. Here is a V shaped tube (Fig. 5), a pole being at each extremity. The pole at the right side (*a*) being negative, you see that the whole of the right arm is flooded with green light, but at the bottom it stops sharply, and will not turn the corner to get into the left side. When I reverse the current and make the left pole negative, the green changes to the left side, always following the negative pole, leaving the positive side with scarcely any luminosity.

In the ordinary phenomena exhibited by vacuum tubes—phenomena with which we are all familiar—it is customary for the more striking illustration of their contrasts of color, to have the tubes bent into very elaborate designs. The positive luminosity caused by the phosphorescence of the residual gas follows all the convolutions and designs into which skillful glass-blowers can manage to twist the glass. The negative pole being at one end, and the positive pole at the other, the luminous phenomena seem to depend more on the positive than on the negative at an ordinary exhaustion such as has hitherto been used to get the best phenomena of vacuum tubes. I have here two bulbs (Fig. 6), alike in shape and position of poles, the only difference being that one is at an exhaustion equal to a few millimeters of mercury—such a moderate exhaustion as will give stratifications or the ordinary luminous phenomena—whilst the other is exhausted to about the millionth of an atmosphere. I will first connect the moderately exhausted bulb with the induction coil, and retaining the pole at one side (*a*) always negative, I will put the positive wire successively to the other three poles with which the bulb is furnished. You will see that as I change the position of the positive pole, the line of violet light joining the two poles changes. In this moderately exhausted bulb, therefore, the electric current always chooses the shortest path between the two poles, and moves about the bulb as I alter the position of the wires.

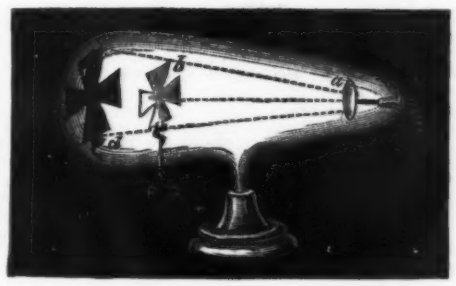
This, then, is the kind of phenomenon we get in ordinary exhaustions. I will now try the same experiment with a tube that is highly exhausted, and as before, will make the side pole (*a'*) the negative, the top pole (*b*) being positive. Notice how widely different is the appearance from that shown by the last bulb. The negative pole is in the form of a shallow cup. The bundle of rays from the cup crosses in the center of the bulb, and thence diverging falls on the opposite side as a circular patch of green light. As I turn

FIG. 8.

the bulb round you will all be able to see the faint blue focus and the green patch on the glass. Now observe, I remove the positive wire from the top, and connect it with the side pole (*c*). The green patch from the divergent negative focus is still there. I now make the lowest pole (*d*) positive, and the green patch still remains where it was at first, unchanged in position or intensity.

This, then, gives us another fact which brings us a little nearer to the cause of this green phosphorescence. It is this—that in the low vacuum the position of the positive pole is of every importance, whilst in a high vacuum it

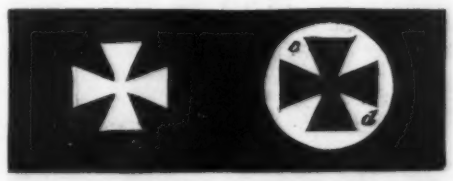
FIG. 9 A.



scarcely matters at all where the positive pole is; the phenomena seem to depend entirely on the negative pole. In very high vacua, such as we have been using, the phenomena follow altogether the negative pole. If the negative pole points in the direction of the positive, all very well, but if the negative pole is entirely in the opposite direction it does not matter: the line of rays is projected all the same in a straight line from the negative.

I have hitherto spoken of and illustrated these phenomena in connection with *green* phosphorescence. It does not follow, however, that the phosphorescence is always of that

FIG. 9 B.

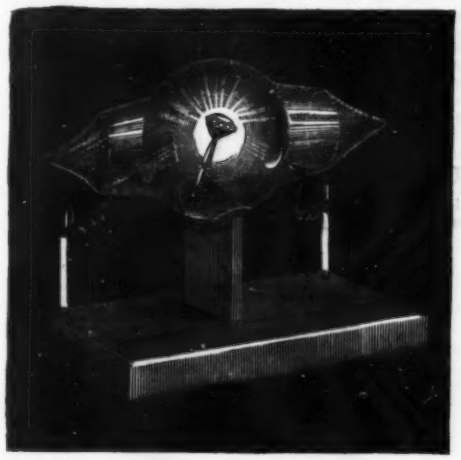


color. This coloration is a property of the particular kind of glass in use in my laboratory. I have here (Fig. 7) three bulbs composed of different glass: one is uranium glass (*a*), which phosphoresces of a dark green color; another is English glass (*b*), which phosphoresces of a blue color; and the third (*c*) is soft German glass—of which most of the apparatus before you is made—which phosphoresces of a bright apple green color. It is therefore plain that this particular green phosphorescence is solely due to the glass which I am using. Were I to use English glass I should have to speak of blue phosphorescence, but I know of no glass which is equal to the German in brilliancy.

My earlier experiments were almost entirely carried on by the aid of the phosphorescence which glass takes up when it is under the influence of the electric discharge *in vacuo;* but many other substances possess this phosphorescent power, and some have it in a much higher degree than glass.

For instance, here is some of the luminous sulphide of calcium prepared according to M. Ed. Becquerel's description. When it is exposed to light—even candle light—it phosphoresces for hours with a rich blue color. I have prepared a diagram with large letters written in this luminous sulphide; before it is exposed to the light the letters are invisible, but Mr. Gimingham has just exposed it in another room to burning magnesium, and now it is brought into the darkened theater you will see the word "ϕ ẃ ƨ"—*light*, a very

FIG. 10.



suitable word for so beautiful a phosphorescence—shining brightly in luminous characters. The first letter, ϕ, shines with an orange light; it is a sulphide of calcium prepared from oyster shells. The other letters, shining with a blue light, are sulphide of calcium prepared from precipitated carbonate of lime. Once the phosphorescence is excited, the letters shine for several hours. I will put the diagram at the back, and we shall see how it lasts during the remainder of the lecture. This substance, then, is phosphorescent to light, but it is also much more strongly phosphorescent to the molecular discharge in a good vacuum, as you will see when I pass the discharge through this tube (Fig. 8). The white plate (*a*, *b*) in the center of the tube is a sheet of mica

FIG. 11.

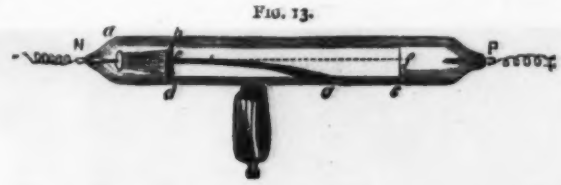
painted over with the luminous sulphide of which the letter ϕ was composed in the diagram you have just seen. On connecting the poles with the coil, the mica screen glows with a strong yellowish green light, bright enough to illuminate all the apparatus near it. But there is another phenomenon to which I now desire to draw attention: on the luminous screen is a kind of distorted star shaped figure. A little in front of the negative pole I have fixed a star (*c*) cut out in aluminum, and it is the image of this star which you see on the screen. It is evident that the rays coming from the negative pole project an image of anything that happens to be in front of it. The discharge, therefore, must come

FIG. 12.

from the pole in straight lines, and does not merely permeate all parts of the tube and fill it with light as it would were the exhaustion less good. Where there is nothing in the way, the rays strike the screen and produce phosphorescence; and where there is an obstacle, they are obstructed by it and a shadow is thrown on the screen. I shall have more to say about this shadow presently; I merely now wish to establish the fact that these rays driven from the negative pole produce a shadow.

I must draw your attention to an important experiment connected with these molecular rays, but unfortunately it is a very delicate one, and very difficult to show to many at once; but I hope, if you know beforehand what to look for, you will all be able to see what I wish to show. In this pear shaped bulb (Fig. 9 A) the negative pole (*a*) is at the pointed end. In the middle is a cross (*b*) cut out of sheet aluminum, so that the rays from the negative pole projected along the tube will be partly intercepted by the aluminum cross, and will project an image of it on the hemispherical end of the tube which is phosphorescent. I think you will all now see the shadow of the cross on the end of the bulb (*c*, *d*), and notice that the cross is black on a luminous ground. Now the rays from the negative pole have been passing by the side of the aluminum cross to produce the shadow; they have been hammering and bombarding the glass till it is appreciably warm, and at the same time they have been producing another effect on that glass—they have deadened its sensibility. The glass has

FIG. 13.



got tired, if I may use the expression, by the enforced phosphorescence. Some change has been produced by this bombardment which will prevent the glass from responding easily to additional excitement; but the part that the shadow has fallen on is not tired—it has not been phosphorescing at all and is perfectly fresh; therefore if I throw this star down—I can easily do so by giving the apparatus a slight jerk, for it has been most ingeniously constructed with a hinge by Mr. Gimingham—and so allow the rays from the negative pole to fall uninterruptedly on to the end of the bulb, you will suddenly see the black cross (*c*, *d*, Fig. 9 B) change to a luminous one (*e*, *f*), because the background is only faintly phosphorescing, whilst the part which had the black shadow on it retains its full phosphorescent power. The luminous cross is now dying out. This is a most delicate and venturous experiment, and I am fortunate in having succeeded so well, for it is one that cannot be rehearsed. After resting for a time the glass seems to partly recover its power of phosphorescing, but it is never so good as it was at first.

We have, therefore, found an important fact connected with this phosphorescence. Something is projected from the negative pole which has the power of hammering away at the glass in front of it, in such a way as to cause it not only to vibrate and become temporarily luminous while the discharge is going on, but to produce an impression upon the glass which is permanent. The explanation which has gradually evolved itself from this series of experiments is this: The exhaustion in these tubes is so high that the dark space, as I showed you at the commencement of this lecture, that extended around the negative pole, has widened out till it entirely fills the tube. By great rarefaction the mean free path has become so long that the hits in a given time may be disregarded in comparison to the misses, and the average molecule is now allowed to obey its own motions or laws without interference. The mean free path is in fact comparable to the dimensions of the vessel, and we have no longer to deal with a continuous portion of matter, as we should were the tubes less highly exhausted, but we must here contemplate the molecules individually. At first this was only a convenient working hypothesis.

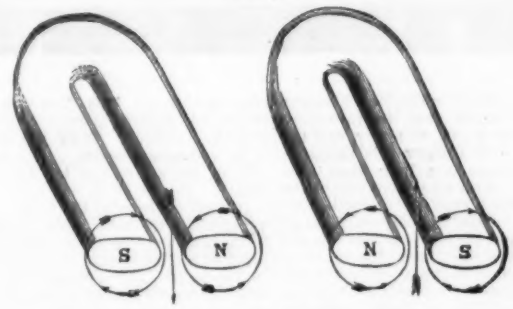
Long continued experiment then raised this provisional hypothesis almost to the dignity of a theory, and now the general opinion is that this theory gives a fairly correct explanation of the facts. In these highly exhausted vessels the mean free path of the residual molecules of gas is so long that they are able to drive across from the pole to the other side of the tube with comparatively few collisions. The negatively electrified molecules of the gaseous residue in the tube therefore dash against anything that is in front, and cast shadows of obstacles just as if they were rays of light. Where they strike the glass they are stopped, and the production of light accompanies this sudden arrest of velocity.

Other substances besides English, German, and uranium glass, and Becquerel's luminous sulphides, are also phosphorescent. I think, without exception, the diamond is the most sensitive substance I have yet met for ready and brilliant phosphorescence. I have here a tube, similar to those already exhibited, containing a mica screen painted with powdered diamond, and when I turn on the coil, the brilliant blue phosphorescence of the diamond can be seen, quite overpowering the green phosphorescence of the glass. Here, again, is a very curious diamond, which I was fortunate to meet with a short time ago. By daylight it is green, produced, I fancy, by an internal fluorescence. The diamond is mounted in the center of this exhausted bulb (Fig. 10), and the negative discharge will be directed on it from below upwards. On darkening the theater you see the diamond shines with as much light as a candle, phosphorescing of a bright green.

In this other bulb is a remarkable collection of crystals of diamonds, which have been lent me by Professor Maskelyne. When I pass the discharge over them I am afraid you will only be able to see a few points of light, but if you will examine them after the lecture, you will see them phosphoresce with a most brilliant series of colors—blue, apricot, red, yellowish green, orange, and pale green.

Next to the diamond the ruby is one of the most remarkable stones for phosphorescing. In this tube (Fig. 11) is a collection of ruby pebbles, for the loan of which I am indebted to my friend Mr. Blogg, of the firm of Blogg & Martin, who placed a small sackful at my disposal. As soon as I turn on the induction spark you will see these rubies shining with a brilliant rich red color, as if they were glowing hot. Now the ruby is nothing but crystallized alumina with a little coloring matter, and it became of great interest to ascertain whether the artificial ruby made by M. Feil, of Paris, would glow in the same manner. I had simply to make my wants known to M. Feil, and he immediately sent me a box containing artificial rubies and crystals of alumina of all sizes, and from those I have selected the mass in this tube which I now place under the discharge: they phosphoresce of the same rich red color as the natural ruby. It scarcely matters what color the ruby is, to begin with. In this tube of natural rubies there are stones of all colors—the deep red ruby and the pale pink ruby. There are some so pale as to be almost colorless, and some of the highly prized tint of pigeons' blood; but in the vacuum under the negative discharge they all phosphoresce with about the same color.

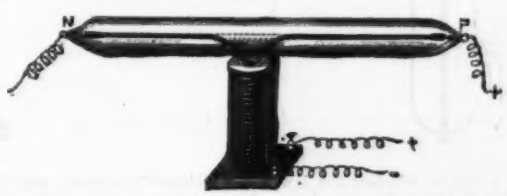
FIG. 14.



As I have just mentioned, the ruby is crystallized alumina. In a paper published twenty years ago by Ed. Becquerel,* I find that he describes the appearance of alumina as glowing with a rich red color in the phosphoroscope (an instrument by which the duration of phosphorescence in the sunlight can be examined). Here is some chemically pure precipitated alumina which I have prepared in the most careful manner. It has been heated to whiteness, and you see it glows with the rich red color which is supposed to be characteristic of alumina. The mineral known as corundum is a colorless variety of crystallized alumina. Under the negative discharge in a vacuum, corundum phosphoresces of a rose pink color.

There is another curious fact in which I think chemists will feel interested. The sapphire is also crystallized alumina, just the same as the ruby. The ruby has a little coloring matter in it, giving it a red color; the sapphire has a coloring matter which gives it a blue color, whilst corundum is white. I have here in a tube a very fine crystal of sapphire, and, when I pass the discharge over it, it gives alternate bands of red and green. The red we can easily identify with the glow of alumina; but what is the green? If alumina is precipitated and purified as carefully as in the case I have just mentioned, but in a somewhat different manner, it is found to glow with a rich green color. Here are the two specimens of alumina in tubes, side by side. Chemists would say that there was no difference between one and the other; but I connect them with the induction coil, and you see that one glows with a bright green color, whilst the other glows with a rich red color. Here is a fine specimen of chemically pure alumina, lent me by Messrs. Hopkin & Williams; by ordinary light it is a perfectly white powder. It is just possible that the rich fire of the ruby, which has caused it to be so prized, may be due not entirely to the coloring matter, but to its wonderful power of phosphorescing

FIG. 15.



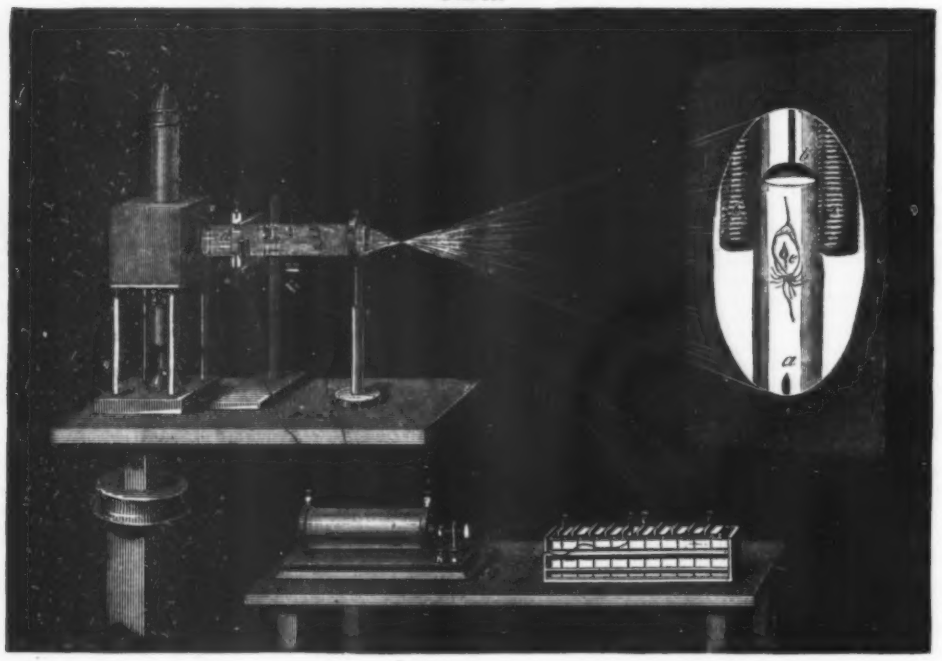
* Annales de Chimie et de Physique, 3d series, vol. lvii., p. 50, 1859.

with a deep red color, not only under the electric discharge in a vacuum, but whenever exposed to a strong light.

The spectrum of the red light emitted by all these varieties of alumina—the ruby, corundum, or artificially precipitated alumina—is the same as described by Becquerel twenty years ago. There is one intense red line, a little below the fixed line B in the spectrum, having a wave length of about 6895. There is a continuous spectrum beginning at about B, and a few fainter lines beyond it, but they are so faint in comparison with this red line that they may be neglected. This line may be called the characteristic line of alumina.

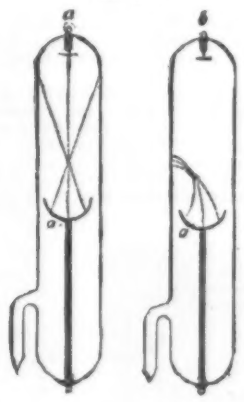
I now pass on to another fact connected with this negative discharge. Here is a tube (Fig. 12) with a negative pole, (*a*, *b*) in the form of a hemi-cylinder, similar to the one you have already seen (Fig. 3), but in this case I receive the rays on a phosphorescent screen (*c*, *d*). See how brilliantly the lines of discharge shine out, and how intensely the focal

Fig. 16.



point is illuminated; it lights the whole table. Now I bring a small magnet near, and move it to and fro; the rays obey the magnetic force, and the focus bends one way and the other as the magnet passes it. I can show this magnetic action a little more definitely. Here is a long glass tube (Fig. 13), very highly exhausted, with a negative pole at one end (*a*) and a long phosphorescent screen (*b*, *c*) down the center of the tube. In front of the negative pole is a plate of mica (*b*, *d*) with a hole (*e*) in it, and the result is that when I turn on the current, a line of phosphorescent light (*e*, *f*) is projected along the whole length of the tube. I now place beneath the tube a powerful horseshoe magnet; see how the line of light becomes curved under the magnetic influence (*e*, *g*), waving about like a flexible wand as I move the magnet up and down. The action of the magnet can be understood by reference to this diagram (Fig. 14). The north pole gives the ray of molecules a spiral twist one way, and the south pole twists it the other; the two poles side by side compel the ray to move in a straight line up or down, along a plane at right angles to the plane of the magnet and a line joining its poles.

Fig. 17.



Now it is of great interest to ascertain whether the law governing the magnetic deflection of the trajectory of the molecules is the same as has been found to hold good at a lower vacuum. The former experiment was with a very high vacuum. This is a tube with a low vacuum (Fig. 15).

On passing the induction spark it passes as a narrow line of violet light joining the two poles. Underneath I have a powerful electro-magnet. I make contact with the magnet, and the line of light dips in the center towards the magnet. I reverse the poles, and the line is driven up to the top of the tube. Notice the difference between the two phenomena. Here the action is temporary. The dip takes place under the magnetic influence; the line of discharge then rises, and pursues its path to the positive pole. In the high exhaustion, however, after the ray of light had dipped to the magnet it did not recover itself, but continued its path in the altered direction.

During these experiments another property of this molecular discharge has made itself very evident, although I have not yet drawn attention to it. The glass gets very warm where the green phosphorescence is strongest. The molecular focus on the tube, which we have just seen (Fig. 12), would be intensely hot, and I have prepared an apparatus by which this heat at the focus can be intensified and rendered visible to all present. This small tube (*a*) (Fig. 16) is furnished with a negative pole in the form of a cup (*b*). The rays will therefore be projected to a focus in the middle of the tube (Fig. 17, *a*). At the side of the tube is a small electro-magnet, which I can set in action by touching a key, and the focus is then drawn to the side of the glass tube (Fig. 17, *b*). To show the first action of the heat I have coated the tube with wax. I will put the apparatus in front of the electric lantern (*d*), and throw a magnified image of the tube on the screen. The coil is now at work, and the focus of molecular rays is projected along the tube. I turn the magnetism on, and draw the focus on the side of the glass. The first thing you see is a small circular patch melted in the coating of wax. The glass soon begins to disintegrate, and cracks are shooting starwise from the center of heat. The glass is softening. Now the atmospheric pressure forces it in, and now it melts. A hole (*e*) is perforated in the middle, the air rushes in, and the experiment is at an end.

Instead of drawing the focus to the side of the glass with a magnet, I will take another tube (Fig. 18), and allow the focus from the cup shaped negative pole (*a*) to play on a piece of platinum wire (*b*) which is supported in the center of the bulb. The platinum wire not only gets white hot, but you can see sparks coming from it on all sides, showing that it is actually melting.

Here is another tube, but instead of platinum I have put in the focus that beautiful alloy of platinum and iridium which Mr. Matthey has brought to such perfection, and I think that I shall succeed in even melting that. I first turn on the induction coil slightly, so as not to bring out its full power. The focus is now playing on the iridio-platinum, raising it to a white heat. I bring a small magnet near, and you see I can deflect the focus of heat just as I did the luminous focus in the other tube. By shifting the magnet I can drive the focus up and down, or draw it completely away from the metal, and render it non-luminous.

I withdraw the magnet, and let the molecules have full play again; the metal is now white hot. I increase the intensity of the spark. The metal glows with almost insupportable brilliancy, and at last melts.

There is still another property of this molecular discharge, and it is this: You have seen that the molecules are driven violently from the negative pole. If I place something in front of these molecules, they show the force of impact by the heat which is produced. Can I make this mechanical action evident in a more direct way? Nothing is simpler. I have only to put some easily moving object in the line of discharge in order to get a powerful mechanical action. Mr. Gimingham, with great skill, has constructed a piece of apparatus which I will presently put in the electric lantern, so that all will be able to see its action. But first I will explain the construction by means of this diagram (Fig. 19). The negative pole (*a*, *b*) is in the form of a very shallow cup.

In front of the cup is a mica screen (*c*, *d*), wide enough to intercept nearly all the molecular rays coming from the negative pole. Behind this screen is a mica wheel (*e*, *f*) with a series of vanes, making a sort of paddle wheel of it. So arranged, the molecular stream from the pole (*a b*) will nearly all be cut off from the wheel, and what escapes over and under the screen will hit the vanes equally, and will not produce any movement.

I now put a magnet (*g*) over the tube, so as to deflect the stream over or under the obstacle (*c*, *d*), and the result will be rapid motion in one or the other direction, according to the way the magnet is turned. I now throw the image of the apparatus on the screen. The spiral lines painted on the wheel show which way it turns. I arrange the magnet to draw the molecular stream so as to beat against the upper vanes, and the wheel revolves rapidly, as if it were an over-shot water-wheel. I now turn the magnet so as to drive the molecular stream underneath; the wheel slackens speed, stops, and then begins to rotate the other way, as if it were an under-shot water-wheel. This can be repeated as often as I like to reverse the position of the magnet, the change of rotation of the wheel showing immediately the way the molecular stream is deflected.

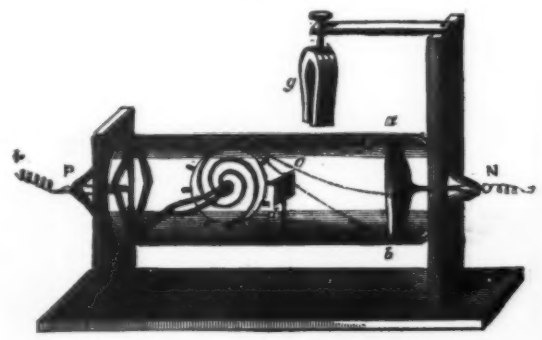
This experiment illustrates the last of the phenomena which time allows me to bring before you, attending the passage of the induction spark through a highly exhausted

Fig. 18.

atmosphere. It will now be naturally asked, "What have we learned from the phenomena described and exhibited, and from the explanations that have been proposed?" We find in these phenomena confirmation of the modern views of matter and energy. The facts elicited are in harmony with the theory that matter is not continuous, but composed of a prodigious number of minute particles, not in mutual contact. The facts also are in full accordance with the kinetic theory of gases—to which I have already referred—and with the conception of heat as a particular kind of energy, expressing itself as a rapid vibratory motion of the particles of matter. This alone would be a lesson of no small value. In science, every law, every generalization, however well established, must constantly be submitted to the ordeal of a comparison with newly-discovered phenomena; and a theory may be pronounced triumphant when it is found to harmonize with and to account for facts which when it was propounded were still unrecognized or unexplained.

But the experiments have shown us more than this: we have been enabled to contemplate matter in a condition hitherto unknown—in a fourth state—as far removed from that of gas as gas is from liquid, where the well-known properties of gases and elastic fluids almost disappear, whilst in their stead are revealed attributes previously masked and unsuspected. In this ultra-gaseous state of matter phenomena are perceived which in the mere gaseous condition are as impossible as in liquids or solids.

Fig. 19.



I admit that between the gaseous and the ultra-gaseous state there can be traced no sharp boundary; the one merges imperceptibly into the other. It is true also that we cannot see or handle matter in this novel phase. Nor can human or any other kind of organic life conceivable to us penetrate into regions where such ultra-gaseous matter may be supposed to exist. Nevertheless, we are able to observe it and experiment on it, legitimately arguing from the seen to the unseen.

Of the practical applications that may arise out of these researches, it would be now premature to speak. It is rarely given to the discoverer of new facts and new laws to witness their immediate utilization. The ancients showed a perhaps unconscious sagacity when they selected the olive, one of the slowest growing trees, as the symbol of Minerva, the goddess of arts and industry. Nevertheless, I hold that all careful honest research will ultimately, even though in an indirect manner, draw after it, as Bacon said, "whole troops of practical applications."

SCIENTIFIC EXPERIMENTAL APPARATUS.

PROFESSORS Wolcott Gibbs, Edward C. Pickering, and John Trowbridge, of Harvard University, have lately corresponded with the leading institutions of learning, and obtained consent for the use of the below-mentioned instruments for purposes of research by properly qualified persons.

LIST OF APPARATUS RELATING TO HEAT, LIGHT, ELECTRICITY, MAGNETISM, AND SOUND, AVAILABLE FOR SCIENTIFIC RESEARCHES INVOLVING ACCURATE MEASUREMENTS.

UNITED STATES COAST AND GEODETIC SURVEY OFFICE.

The use of this apparatus may be had at the office, under appropriate regulations. Applications must be made to Capt. C. P. PATTERSON, Superintendent United States Coast Survey.

1. *Comparators of Length:*

a. Saxton's pyrometer, or mirror comparator, for end measures.

b. Repsold's contact-level comparator, for end measures.

c. Saxton's tracing and comparing machine, for line measures.

d. Hilgard's comparator, for line and end measures for any length between three and forty inches.

e. Rutherfurd's micrometer, with two screws at right angles, and circle of position for measuring stellar and solar photographs.

2. *Standards of Length:*

a. Standard iron meter of original committee for establishing metric system (end measure).

b. Standard British yard (line measure).

" " " (end measure).

Eighty-four-inch scale, divided to tenths of inches, made by Troughton and compared throughout by Hassler.

c. Decimeter divided into centimeters and millimeters, compared with the original standard meter.

d. Copy of toise, accurately compared.

3. *Apparatus for Weighing.*—Balances of precision for maximum charges of 100, 10, and 1 kilogrammes, and 100 and 1 grammes.

4. *Standard Weights.*—Standard troy and avoirdupois pounds; kilogramme in platinum and in brass accurately compared.

AMERICAN ACADEMY OF ARTS AND SCIENCES, BOSTON.

Applications for use must be made to Professor JOSEPH LOVERING, Chairman of the Rumford Committee, Cambridge, Mass.

1. *Meyerstein's Spectrometer.*—Aperture of collimator and telescope, 3·3 centimeters; magnifying power of telescope 18 times; graduated circle reads by means of two micrometers to two seconds. Instrument intended to be used with a diagonal eye piece for obtaining reflection at right angles to the reflecting surface. It is not well adapted for measuring indices of refraction, except by the special method for which the instrument was designed.

2. *Large hollow prism* of glass, with movable glass faces, held in their places by springs. Angle 60°.

3. *Prof. J. Trowbridge's Electro-Dynamometer.*—Instrument for measuring the strength of powerful electric currents such as are produced by dynamo-electric machines. Mean radius of fixed coils 153·3 millimeters. Instrument described in Proceedings of American Academy of Arts and Sciences, Oct. 9, 1878.

4. Thomson's galvanometer, resistance 6 ohms.

5. *Micrometer-level*, constructed by Alvan Clark & Sons. Telescope, 45 centimeters focal length and 4 centimeters aperture, in Y's moved by vertical micrometer screw reading to 0·3″ by estimation of tenths. Intended also for use with eye-piece micrometer. One division of level tube (0·15 cm.)=8·7″. Transverse level and slow motion for rotating telescope in Y's. Horizontal finding circle graduated to degrees.

6. *Light micrometer-level.*—Telescope 21 centimeters focal length and 25 centimeters aperture, in Y's moved by vertical micrometer screw, reading to 1·4″ by estimation of tenths. One division of level tube (0·25 centimeter)=1·8″. Horizontal finding circle graduated to degrees.

7. *Microscope-tube* and accessories, specially designed for measuring spectrum photographs. Also a *standard plate* of 24ths of an inch; rulings on glass by Prof. William A. Rogers.

8. *A large double induction coil* of the form devised by Prof. John Trowbridge.

9. *Apparatus for the determination of the mechanical equivalent of heat.* Devised by Prof. Henry A. Rowland, of Johns Hopkins University, and now in his charge.

HARVARD UNIVERSITY.—RUMFORD CABINET.

In charge of Professor WOLCOTT GIBBS.

1. *A spectrometer* by Brunner Frères, of Paris. The instrument has a single graduated circle 10 centimeters radius, reading by two verniers to 5 seconds of arc, and by a micrometer eye piece to about 2 seconds. The telescope and collimator have 33 centimeters focal length, and 3·4 centimeters aperture. The micrometer is provided with cross and also with parallel spider lines, and with a separate collimating eye piece. The spectrometer stands upon a plate of metal which can be made to revolve, so that measurements by repetition are practicable. The instrument is in perfect adjustment, and has everything necessary for the determination of wave lengths and of indices of refraction. In connection with it the Rumford Cabinet possesses:

2. Two gratings, Nos. 1 and 2, ruled on speculum metal by D. C. Chapman with Mr. Rutherfurd's engine. One of these, No. 1, has 8,648 lines to the inch and a ruled surface (4·3 cm. ×5·2 cm.) The other has 17,296 lines to the inch and the same ruled surface as No. 1. They may be adjusted to the spectrometer above described by plate-holders constructed by William Grunow, of New York, with all necessary requirements for the measurement of wave lengths.

3. A collimator, 0·1600 meter focal length and 6·5 centimeters aperture, mounted upon a stand and specially adapted to the study of the extreme visible red and violet ends of the spectrum. Object glass by Alvan Clark & Sons. A quartz lens of same focal length is to be added to this instrument from the workshop of Steeg & Reuter, in Homburg vor der Höhe, as well as a telescope with quartz objective and eye piece for observing the ultra-violet spectrum.

4. *A porte-lumière*, by Duboscq. A Foucault's heliostat has been ordered, and may be expected in the course of the summer.

5. *Vierordt's apparatus* for measuring the intensity of light corresponding to any part of the visible spectrum. Telescope and collimator 25 centimeters focal length. Apertures, 2·8 centimeters and 2·1 centimeters. The instrument was made by Schmidt & Haensch, of Berlin, and is complete with prism and colored glasses.

6. *A direct-vision spectroscope*, with 2 sets of 9 prisms each. Set 1 contains 4 prisms of carbonic disulphide and 5 of crown glass. Set 2 consists of 4 prisms of flint and 5 of crown. The length of the instrument is 60 centimeters. It is provided with a scale telescope, and the observing telescope has the usual angular motion. This instrument is also by Schmidt & Haensch.

7. *An inductorium*, by Apps, of London, giving a 4-inch spark.

8. *Three thermometers*, by Baudin, of Paris, reading to ·01 degree Centigrade·

No. 1. Reading from 0·6° to 12° Centigrade.
No. 2. " " 12° to 23°.
No. 3. " " 23° to 35°.

In these instruments the weights of the bulbs, stems, and contained mercury are given.

9. *Edison's tasimeter*, made by Patrick & Carter, of Philadelphia, and adjusted by Mr. Edison. See *American Journal of Arts and Sciences*, 3d series, Vol. XVII., p. 52. A galvanometer suited to this instrument will be found in the cabinet in charge of Prof. Trowbridge, together with the requisite batteries and Wheatstone's bridge.

In connection with these instruments the following, belonging to the Rumford Professor, are also available:

1. *A large spectroscope* with telescope and collimator of 4·75 centimeters aperture and 5·5 centimeters focal length. Magnifying power from 8 to 60 times. Object glasses by Fitz, of New York. Six hollow prisms of carbonic disulphide—glass faces 6×8 centimeters—arranged on Mr. Rutherfurd's plan, so that all the prisms are constantly in the position of minimum deviation. The stand, observing telescope, and prisms of this instrument may be used in connection with the long collimator belonging to the Rumford Cabinet.

2. *A large hollow prism*, with angle of 30°—glass faces 6× 8·5 centimeters—for Prof. Gibbs' solution of phosphorus and sulphur in carbonic disulphide. See *American Journal of Science and Arts*, Vol. IV., p. 6, 2d series.

3. *Two flint glass prisms*—faces 8·5×5 centimeters—which may be used singly or together. Angles of 60°.

4. *Prof. Gibbs' double or compensating prism* for the study of absorption spectra. See *American Journal of Arts and Sciences*, Vol. IV., p. 8.

5. *Five gratings* ruled with Mr. Rutherfurd's engine:

No. 1. Ruled on speculum metal, 6,480 lines to the inch. Ruled surface 2·1×2·8 centimeters. Metal a little tarnished.

No. 2. Ruled on glass and silvered, 8,640 lines to the inch; 7,021 lines upon a ruled surface 2x2·7 centimeters. Covering plate of glass cemented with Canada balsam.

No. 3. Ruled on glass for spectra by transmission, 6,480 lines to the inch. Ruled surface 1·7×2·7 centimeters.

No. 4. Ruled on glass for transmission of light, 12,960 lines to the inch. Ruled surface 1·3×2·7 centimeters.

No. 5. Ruled on glass and silvered; 13,321 lines on a space 19×24 centimeters, with covering glass cemented by Canada balsam.

Kirchhoff's, Angström's, and Mascart's maps of the spectrum.

Mr. Rutherfurd's original photographs, together with the German lithographic reproduction of the same.

Mr. Rutherfurd's recent photographs taken with the diffraction spectrum. Thalen's map of the absorptive bands of iodine vapor.

The thermometers by Fastré, of Paris, carefully compared with an air thermometer reading from 0° to 100° C.

HARVARD UNIVERSITY.—DEPARTMENT OF PHYSICS.

In charge of Professor JOHN TROWBRIDGE.

1. *Edelmann's* instrument for measuring horizontal and vertical intensity of earth's magnetism.

The peculiarity of this instrument consists in its allowance of a long suspension, and in its torsion head.

2. *A standard ohm*, and two boxes of resistance coils running from one to five thousand ohms.

3. *An induction coil* made in the horseshoe form and provided with iron plates for armatures. The two induction coils comprise a resistance of 12,000 ohms.

4. *Galvanometer for absolute measure.*—Maker: Edelmann, Munich. A short coil minor instrument, adapted for absolute measures by certain methods. Resistance, six ohms.

5. *Thomson's Reflecting Galvanometers.*—One of 5,880 ohms, resistance—a differential instrument.

One of six ohms resistance, adapted for heat measures.

6. *Thomson's Quadrant Electrometer.*—Made by White, of Glasgow.

7. *Cathetometer.*—Maker: Perreaux, Paris. Reads by vernier to 2-100ths of millimeter, or by micrometer to 1-100th of a millimeter. Focal length of objective, 13 centimeters; magnifying power of telescope 30 times.

8. *Dividing Engine.*—Maker: Perreaux, Paris. Screw, 61 centimeters long. Pitch of screw, one-half of a millimeter. Micrometer reads to one four-hundredth of a millimeter. Instrument adapted only for graduating tubes and scales, or for comparison of graduations.

9. *Large Spectroscope.*—Designed by Professor J. P. Cooke, of Harvard University. Two trains of prisms. One of nine bisulphide of carbon prisms of 45°. One of nine flint-glass prisms of 45°. Graduated circle reading to 10 seconds, also a micrometer eye-piece. Magnifying power of telescope, 10 times; focal length of objective, 46 centimeters; aperture, 5·5 centimeters.

10. *Reading Telescope and Scale.*—On brass leveling stand. Telescope provided with two objectives: one for short, the other for long, distances.

Magnifying power for long distances, 22 times.
" " " short " 30 "
Focal length of the objective for long distances, 30 cm.
" " " " short " 23 "
Aperture of objectives, four centimeters.

HARVARD UNIVERSITY.—ASTRONOMICAL OBSERVATORY.

In charge of Professor E. C. PICKERING.

LIST OF INSTRUMENTS NOT IN CONSTANT USE, AND AVAILABLE FOR RESEARCH.

1. *East transit circle*, by Troughton and Simms, of London. Aperture of telescope, 4¼ inches; focal length, 5 feet. Described in Vol. I., pt. 1, of the Annals of the Observatory, p. 46.

2. *West Equatorial*, by Alvan Clark & Sons, of Cambridge. Aperture of telescope, 5¼ inches; focal length, 7⅛ feet. Described in Vol. VIII. of the Annals of the Observatory, p. 31.

3. *Portable transit instrument*, by Herbst, of Pulkowa. Aperture of telescope, 2¾ inches; focal length, 33 inches. Eye-piece at end of axis. Described in Vol. VIII. of the Annals of the Observatory, p. 28.

4. *Bowditch Comet-seeker.*—Aperture, 4 inches; focal length, 33 inches. Described in Vol. VIII. of the Annals of the Observatory, p. 32.

5. *Telescope*, by Lerebours. Aperture, 3 inches; focal length, 50 inches.

6. *Telescope*, by Alvan Clark & Sons. Aperture, 3⅛ inches; focal length, 39 inches. Object glass slightly damaged.

7. *Variation transit*, by Troughton & Simms, of London. Aperture of telescope, 1¾ inches; focal length, 18 inches.

8. *Traveler's transit theodolite*, No. 3537, by L. P. Casella.

9. *Sextant*, by Spencer, Browning & Rust.

10. *Spectroscope*, by Troughton & Simms, of London, with two prisms, and Professor Winlock's apparatus for recording observations, as described in Vol. VIII. of the Annals of the Observatory, p. 33.

11. *Spectroscope*, by J. Browning, of London, with one prism, and Professor Winlock's apparatus for recording observations.

12. *Spectroscope*, by Alvan Clark & Sons, of Cambridge, with five prisms and reflecting prism to send the light a second time through them. Dispersive power exceeding that of 22 ordinary prisms. Prisms not movable. Described in Vol. VIII. of the Annals of the Observatory, p. 35.

13. *Lens of plate glass.*—Focal length, about 40 feet; aperture, 4 inches.

14. *Lens corrected for chemical rays.*—Focal length, 32 feet 5 inches; aperture, 4 inches.

15. *Photometer*, by Ausfeld, of Gotha, on plan of Professor Zöllner.

16. *Occultator* (for computation of occultations), on plan of Rev. Thomas Hill.

17. *Position circle*, read by verniers to minutes of arc.

18. *Thermometric chronometer*, by C. Frodsham, of London, No. 3424, constructed so as to increase its daily rate by 6·11″ on a reduction of one degree Fahrenheit.

19. *Clock*, by W. Bond & Son, of Boston, No. 312.

20. *Small chronograph*, by Herbst, of Pulkowa.

21. *Portions of the magnetic apparatus* described in Vol. I., pt. 1, of the Annals of the Observatory.

Property of Professor WILLIAM A. ROGERS.

1. Small line and circle graduating engine. This machine is designed for all kinds of graduations, in which the length of the line to be ruled does not exceed 2 inches. The errors of the screw for one-thousandth of an inch have been carefully investigated. It is not automatic in its action, and hence it is not adapted to ruling diffraction gratings. The circular graduations are only approximate.

2. Machine for original graduation of circles from 1 inch to 15 inch disk.

3. Machine for shaping and polishing diamonds for marking on glass and on all kinds of metals.

4. Microscope comparator for short lengths.

5. Comparator for long standards of length.

6. In process of construction at the Waltham Watch Factory: A universal line graduation engine. This machine is designed:

(1). To rule Nobert's bands.
(2). To graduate both short and long standards of length.
(3). To rule diffraction gratings in which:

(*a*) Any required relation between the relative width of the lines and the spaces may be secured.

(*b*) Errors of any required magnitude may be introduced, whether individual or systematic, without interference with the remaining graduations.

Professor Rogers is prepared:

(*a*) To make centimeters and inches which are aliquot parts of the coast survey standard meter and yard, marked *Y. & M., No.* 2.

(*b*) To compare meters and yards, or any aliquot parts of the same, with standards.

(*c*) To determine the distance between the end lines of diffraction gratings in terms of the coast survey yard or meter, *Y. & M., No.* 2.

(*d*) To compare end measures with line measures.

(*e*) To make transfer copies of the yard and meter adopted as a standard.

(*f*) To determine the coefficients of expansion of metal bars of any length not exceeding 44 inches.

HARVARD UNIVERSITY.—MEDICAL SCHOOL, PHYSIOLOGICAL LABORATORY.

In charge of Professor H. P. BOWDITCH.

1. *Thomson's galvanometer*, No. 26, Elliott Brothers. Resistance at 55° F. = 5,995 B. A. units.

2. *Wiedemann's galvanometer*, with mirror and two pair of coils of 4,000 and 98 turns respectively.

3. *British Association unit of resistance*, No. 74, right at 15·5° C.

4. *Pendulum myograph*, described by Dr. J. J. Putnam at the American Academy, March, 1879.

5. *Cylinder chronograph:* Baltzar, Karolinen Strasse, 14, Leipsic.

6 *Chronograph*, with long roll of paper. Baltzar. Leipsic.

7. *Clock* for making or breaking an electrical circuit once in 1, 2, 3, 4, 5, 10, 15, 20, 30, or 60 seconds, the duration of the make or break variable from 0 to 4 seconds.

STEVENS INSTITUTE OF TECHNOLOGY, HOBOKEN, NEW JERSEY.

For the use of this apparatus application may be made to Professor A. M. MAYER.

1. *Apparatus for the determination of coefficients of expansion.*—Consists of the tube (invented by Professor Mayer) to hold the rod under measurement. This tube is so constructed that the rod up to its terminal planes is kept permanently at the temperature of melting ice, or at the boiling point, or at any intermediate temperature, by passing a current of water or hot oil through the tube; at the same time the terminal planes of the rod are exposed for abutment against micrometer screws, etc. The rod is supported in the tube at quarters of its length from its ends, and the weight of tube and inclosed rod is taken off the V's of the apparatus by straps and spring balances.

The measuring part of the apparatus is entirely distinct, and at a distance from the tube. The tube is only placed in contact with the measuring apparatus *at the moment* of making the measurement.

The measures are made by Saxton's reflecting comparator, or by micrometer screws brought up to the ends of the rod, and contact determined by the closing of a voltaic circuit.

Successive contacts, made by successively placing the rod (cooled to melting ice), give a range of measures on a rod one meter long, equal to about 1-30,000th of an inch. Micrometer screws, pitch 1-50th and 1-100th inch.

2. *Vertical comparator*, with contact level, micrometer screw, pitch = 1-100th inch. Well made, heavy cast-iron frame of **T** section, mounted on a cast-iron tripod base.

3. *Apparatus for the comparison of yard and meter* (yard or line measures), by Airy's method. Massive cast-iron plate with guides, two micrometer microscopes, with apparatus for handling measures.

4. *Spectrometer.*—Circle divided by Brunner of Paris, reading by vernier to 5'. Telescopes: one set, one inch aperture, 10 inch focus. Another set: collimator, 5 feet long, and observing telescope, 18 inches focus. (*Property of Prof. Mayer.*)

5. *Interferential refractometer of Arago.*—Tube of one meter for holding gas whose index of refraction is to be measured. Collimator, six inches; observing telescope, three-quarters of a meter focus.

6. *Two of Hipp's chronoscopes.*

7. *Electric clock*, to be used in connection with inductorium and rotating cylinder, to determine the number of vibrations of tuning forks and other solid bodies.

8. *Spherometer*, by Brunner, of Paris, furnished with a contact lever. Pitch of screw, 0·5 millimeter.

9. *Full sets of resistance coils*, condensers, and high and low resistance Thomson galvanometers.

Massachusetts Institute of Technology.—Department of Physics.

In charge of Professor Charles R. Cross.

1. *Cathetometer*, by Staudinger. Scale graduated to millimeters; length, 1,020 millimeters. Vernier reads directly to 1-20th millimeter. Focal length of telescope is 280 millimeters. One division of level corresponds to 5".

2. *Dividing engine*, by Buff and Berger. The microscope is carried by two screws moving at right angles to each other, so as to give two co-ordinates. The pitch is 1-20th inch, and the length of the screws, 16 inches and 4·5 inches respectively. Circles are divided into 100 parts, read by estimation to tenths. The instrument is arranged especially for measurement rather than for graduation.

3. *Spectrometer*, by Clark. Furnished with five 60° and one 30° prisms, the latter silvered on its rear surface. A greater or less number of prisms can be used at will. Face of prisms 5·7 centimeters by 7·3 centimeters. Focal length of telescope, 70 centimeters; diameter of object glass, 5·2 centimeters. Diameter of circle, 43·5 centimeters, reading to 10" by verniers. Smaller angles are measured by spider-line micrometer. The same telescope serves as collimator and observing telescope, the method of reflection from the silvered surface of the glass being used.

4. *Diffraction grating*, ruled by Chapman on Mr. Rutherfurd's engine. 17,256 lines to an inch; 30,600 spaces. Area of ruling, 4·5 centimeters square.

5. *Two prisms of quartz*, 60°, faces 5·5 centimeters by 4·0 centimeters. Also various prisms of flint glass and heavy glass.

Eaton's direct-vision prism of glass and carbon disulphide. Small direct-vision prisms of glass.

6. *Polarimeter* of Professor Pickering, for sky-polarization. See *Proc. Am. Acad.*, Vol. IX.

7. *Wheatstone's bridge*, by Elliott, measuring from ·001 to 1,000,000 ohms.

8. *Thomson's long-coil galvanometer.*—Resistance, 3,000 ohms. Thomson's short-coil galvanometer for thermo-electrical work; resistance, 6-10 ohm.

9. *B. A. divided meter bridge.*

10. *Tangent galvanometer.*—36 coils, 26 centimeters radius. Gaugain tangent and sine galvanometer. Cosine galvanometer.

11. *Induction coil*, by Ritchie, giving 6-inch spark

Columbia College, New York.

In charge of Professor O. N. Rood.

1. *Newman's standard barometer;* diameter of tube, 0·6 inch; reads to 1-500 inch.

2. *Grunow's spectrometer.*—Focal length of lenses, 14 inches; diameter of circle, 9 inches; aperture, 1·3 inches; reads to 10 seconds.

3. *Cathetometer.*—Length, 800 mm., focal length of telescope, 10 inches; aperture, 1·1 inches. Provided with extra object-glass for reading at short distances.

4. *Wild's photometer*, simple construction, diameter of circle, 6 inches.

5. *Apparatus* for measuring the velocity of sound in rods of wood by means of longitudinal vibration. Described in *American Journal of Science*, Vol. XVII.

6. *Magneto-electric machine*, by Wallace (no motor).

7. *Ruhmkorff's diamagnetic apparatus.*

8. *Tangent compass.*—Diameter of circle, 13·5 inches.

9. *Original Siemens unit.*

10. *Helmholtz apparatus for vocal sounds.*

11. *Koenig's phonautograph.*

12. *Koenig's cylinder* for determining the vibrations of tuning forks.

13. *Nachet's large inverted microscope.*

14. *Koenig's monochord.*

15. *Lissajou's comparateur.*

16. *Comparateur* for the standard yard.

Johns Hopkins University.—Physical Laboratory.

In charge of Professor Rowland.

The list does does not include apparatus for demonstration.

ACOUSTICS.

All the ordinary apparatus by Koenig, of Paris, including Helmholtz's double sirens, Lissajou's vibrating microscope, Hastings' pendulum comparator, etc.

OPTICS.

1. *Meyerstein spectrometer*—large model. The circle is of 16 centimeters radius, divided on silver to 6' and reading by two microscopes to 2". The probable and periodic errors of graduation have been investigated, and are given in the *American Journal of Science*, Vol. XV., p. 270. Having a common axis with the large circle is a table rotating independently, 6·5 centimeters radius, graduated on silver limb and by two verniers to single minutes. The massive stand has a joint by which the circle may be brought into a vertical plane. Aperture of telescope and collimator, 4·0 centimeters; focal length, 34 centimeters; powers, from 13 upward. A smaller telescope, 2·0 centimeters aperture, 18·0 centimeters focal length, power 7, may be placed on a third support rigidly connected with the microscope bearers. The accessories of this instrument are:

(*a.*) Two telescopes with Nicol prisms before objectives: longer diagonals of prisms, 2·0 centimeters; length of telescopes, 20·0 centimeters; power, 3; position angles of prisms read by circles of 3·5 centimeters radius to minutes of arc.

(*b.*) Babinet's compensator with wedge of 3 centimeters available length.

(*c.*) High power collimating ocular.

(*d.*) Low power collimating ocular.

(*e.*) Three micrometer eye-pieces.

2. *Spectrometer*, by Schmidt and Haensch. The circle has a silver limb 16 centimeters radius, divided to 6' and read by microscopes to 2". Table in center has a graduation 6·9 centimeters radius, reading by verniers to 1'. Aperture of objectives of telescope and collimator, 3·9 centimeters; focal length, 35·0 centimeters; power, 13. The angle between lines of collimation of telescope and collimator may be read by small circle to single degrees.

3. *Steinheil's spectroscope.*—The clear aperture of train, including two 60° prisms, is 4·0 centimeters. Focal length of collimator and telescope, 32·5 centimeters; powers, 8, 12, etc. Photographic scale.

4. *Silbermann's Heliostat, etc.*—This instrument, by Duboscq, has two mirrors 18·0 centimeters by 9·0 centimeters, one silver under glass and the other silver. Also, *porte-lumière.*

5. *Jamin's interferential refractometer*, with tubes 100 centimeters long, for the study of refraction in gases, and a glass trough 20 centimeters long for liquids, by Duboscq.

6. Complete apparatus for the study of phenomena of interference, by Duboscq.

7. *Photographic apparatus.*—Objective 6·1 centimeters aperture, and about 40 centimeters focal length for plates; 10x12 inches, by Steinheil. Dark room, collection of chemicals, and everything necessary for experiments on the subject.

8. *Becquerel's phosphoroscope*, by Duboscq.

9. *Polarizing apparatus*, from Steeg; also from Duboscq.

10. Apparatus for producing monochromatic light of any color. Designed by Hastings and made by Schneider.

11. *Prisms, gratings, etc.*

a. Hollow prism from Meyerstein; aperture, 6·1x5·2 centimeters.

b. Hollow prism from Steinheil; aperture, 2·2 centimeters.

c. Thallium glass prism from Steinheil; aperture, 4·8 centimeters.

d. Two flint glass prisms from Steinheil; aperture, 4·7 centimeters.

e. Crown glass prisms from Steinheil; aperture, 4·8 centimeters.

f. Two quartz prisms from Steeg; faces, 3·4x3.0 centimeters.

g. Iceland spar prism; faces, 2·6x2·2 centimeters, by Steeg.

h. Two rock-salt prisms, faces, 5·0x4·0 centimeters, by Steeg. Also rock-salt lens.

i. Large Nicol's prism, largest diagonal 6·5 centimeters. Also a number of smaller ones.

j. Gratings on speculum metal, 4·3x3·9 centimeters, with 8,648 lines to the inch, and 4·4x4·4 centimeters, with 17,396 lines to the inch, and a smaller glass grating, with 8,648 lines to the inch, all by Chapman with Rutherfurd's engine.

Kirchhoff's, Angström's, and Rutherfurd's maps of the solar spectrum.

k. Old telescope by Dollond. Objective about 4 inches diameter and 6 feet focal length.

ELECTRICITY AND MAGNETISM.

The distinguishing feature of the apparatus for these subjects is its accuracy and the determination of the constants in absolute measure. The collection is unique in this respect.

12. *Rowland's absolute electrometer* for potentials represented by sparks of about 0·1 to 1 inch. Designed on Sir Wm. Thomson's guard-ring principle, and constructed by Edelmann, of Munich. Guard-ring, 33·5 centimeters, and can be separated about 7 centimeters, the distance being read by vernier to 0·01 centimeter. Movable disk, 10 centimeters diameter, and *firmly* attached to arm of a balance sensitive to 1 mgr. Balance moves only 0·01 centimeter, and means of two distances of the disks are taken, the one to move it to upper and the other to lower stop. Weights of from 1 to 5 grammes ordinarily used. *Disks ground and polished to mirror surface after nickel-plating.*

13. *Rowland's electrostatic standard condenser.*—Constructed by Grunow, of New York. One sphere within the other *nickel-plated and ground to mirror surface*, with extra ball for interior. Balls, 7 and 8 inches diameter. Hollow sphere, 10 inches diameter. Apparatus for centering. Radii determined by loss of weight in water. Can be charged and discharged any number of times at rate of three per second, by means of fine wires which pass in momentarily from outside, and so do not change the capacity much. Any condenser can be compared with it by means of an electrometer.

14. *Thomson's quadrant electrometer*, by White, of Glasgow, with Thomson's key.

15. *Condenser*, 1·3 microfarad, by Elliott.

16. *Commutators* for high (say 1 inch spark) as well as low tension.

17. *Rowland's galvanometer* for the absolute measurement of discharges of high tension. Constructed by Rowland & Schneider. Coils wound with paper between, and boiled in paraffine *in vacuo* at 100° C., to be thoroughly dry. Needle shielded from electrostatic action, and deflection read by mirror and scale. Number of coils about 11,000. Constant on the cm. gr. second system 19091·=G of Maxwell, as determined by comparison with galvanometer described in *American Journal of Science*, Vol. XV., p. 334. See No. 27, below.

18. *Rowland's absolute galvanometer* for the measure of quick, weak currents. Constant, 1838·2. See *American Journal of Science*, Vol. XV., p. 334. Constant very accurately known. 1,780 turns. Can be used as sine galvanometer or with mirror and scale. Horizontal circle reads to 1', but is readily estimated to 30". Telescope and bar for determining horizontal intensity in exact position of instrument.

19. *Rowland's tangent galvanometer*, brass circle, 50 centimeters diameter. Circle graduated to 15' and 20 centimeters diameter. From 1 to 243 turns can be used, the constant of each set being known with great accuracy. Made by Meyerstein, but altered and wound and coils measured by Rowland.

20. *Two Thomson's galvanometers* of high and low resistance, the first differential with coils around both needles and set of shunts. Made by Elliott, of London.

21. *Two Nobili Astatic galvanometers*, by Elliott, and one by Salleron.

22. *Wiedemann galvanometer*, with two sets of coils and two kinds of needles. Reading by mirror and scale.

23. *Galvanometer* with large wire for experiments on the damping effect of the coils on the needle, and for determining resistances in absolute measure. Designed by Rowland and made by Schneider, instrument maker at the University.

24. *Tangent galvanometer*, wooden circle, with variety of coils of known constant.

25. *Mirror galvanometer.*

26. *Rowland's wooden circle*, 84 centimeters diameter, carefully laid up out of maple wood, and containing several grooves on the edge to contain single wires. It is used to surround a galvanometer, when, by aid of the electro-dynamometer, the horizontal intensity can be measured at any instant. Extremely useful.

27. *Electrodynamometer* of form given in "Maxwell's Electricity," Vol. II., p. 330. Outer circles about 27·5 centimeters diameter, with 240 windings on each side. Constant, G, of outer coils 78·371 on cm. qm. second system. Inner coils about 5·5 centimeters diameter, with 63 coils in each. Moment of inertia of suspended coil accurately known. Constant calculated and also determined by comparison with a tangent galvanometer made of the circle described above. Made (partly) by Gurley, of Troy, and circles wound and measured by Rowland.

28. *Electrodynamometer*, Quincke's form for weak currents. Made by Edelmann, of Munich.

29. *Standards of resistance*, mounted so that they can be placed in water 1 and 10 ohms, by Elliott; 10, 100, and 1,000 ohms, by Warden, Muirhead & Clark, of London; also mounted in another style—1, 10, and 100 Siemens units, by Siemens & Halske, of Berlin. Also three copies of coil whose absolute resistance was determined by Rowland as 34·719 *earthquad.* ÷ sec.

30. *Resistance coils* in boxes, 1 to 10,000, and 10,000 to 100,000 ohms, by Elliott, and 1 to 10,000 Siemens units by Edelmann.

31. *Rowland's Resistance Comparator.*—Ten coils, of 10 ohms each, arranged so that they can be joined in series or abreast, thus making 1, 10, and 100 ohms, besides intermediate ones. Made by Schneider and adjusted by Rowland.

32. *Two bridges* of Jenkins' form for the accurate comparison of equal resistances, and also a Wheatstone bridge, having wire of platinum-iridium alloy one meter long, by Elliott.

33. *Magneto-electric machine* for 1,200 candles, by Siemens Brothers, London, with engine to drive it, and both Siemens' and Foucault's lamps. Also battery of 60 large bichromate cells.

34. *Ruhmkorff coil*, spark 15 or 20 centimeters, by Ruhmkorff, of Paris.

35. *Rowland's earth inductor*, with *brass* circle, 30 centimeters diameter, wound and measured by Rowland. Made by Meyerstein, of Göttingen.

36. *Ruhmkorff's apparatus* for diamagnetism. Made by Ruhmkorff, of Paris.

37. *Electric Clocks* beating seconds from regulator.

38. *Rowland's Standard of Electromagnetic Induction.*—Three coils on brass cylinders which can be placed accurately on top of each other. See *American Journal of Science.* Mutual potential of coils with unit current 3,775,500, 2,561,974, 2,051,320, etc., on the cm. grm. second system.

39. *Telescopes, Scales, and Mirrors.*—Silvered brass millimeter scale by Brown & Sharp. Mounted telescope by Steinheil, objective 4·0 centimeters diameter, with three oculars, giving powers of 20, 40, and 80. Unmounted telescope by Steinheil, objective 2·7 centimeters diameter, and 3 oculars.

Mounted telescope and paper scale by Meyerstein; objective, 2·7 centimeters diameter.

40. Thin mirrors and plain parallel glasses by Steinheil. The mirrors give a *perfect image with the highest magnifying power.*

Thomson's Replenisher on large scale for use with electrometer, Holtz and friction machines, Leyden jar batteries, Geissler tubes, etc.

HEAT.

41. *Rowland's Instrument for comparing the mercurial with the air Thermometer* between 0° and 100° C.—Constructed by Schneider, instrument maker at the University. Readings seldom differ more than 0·02° or 0·03° C. at any one point, especially up to 40° C., and a change is contemplated which will much improve it.

42. *Rowland's Instrument for comparing Thermometers* from 0° to about 300° C.—Constructed by Schneider. Accurate to about 0·1° C.

43. *Regnault's Air Thermometer*, Golaz, Paris.

44. *Jolly's Air Thermometer*, by Berberich, Præparator, Phys. Inst. Univ. of Munich.

45. *Regnault's Apparatus for Expansion of Gases* both at constant pressure and constant volume, also Regnault's form of Rudberg's apparatus, Golaz, Paris.

46. *Regnault's Apparatus for Tension of Vapors*, including: *a.* The boiler; *b.* The reservoir for compressed air; *c.* A rotary pump for compressing gases; *d.* Mercurial manometer. Maker, Golaz, Paris.

47. *Regnault's Apparatus for Specific Heat* of solids, Golaz, Paris.

48. *Regnault's Hygrometer with Aspirator*, Golaz, Paris.

49. *Thermometers*, about 30 or 40, principally by Baudin, Paris, and Geissler, of Bonn. Many of these have been compared with the air thermometer as well as with standards by Fastré, Casella, or from Kew. The thermometers up to 40° C. undoubtedly represent the air thermometer more accurately than any so far constructed, and are supposed to agree with it to about 0·01° C. They have been compared with it eight times during about one year or more. The error in calorimetric investigations from using uncompared thermometers *may* amount to two per cent.

50. *Rowland's Apparatus for determining Change of specific Heat of Liquids* with temperature. Constructed by Schneider.

51. *Dulong's Apparatus for the Heat of Combustion*, Salleron, Paris.

52. *Melloni's Apparatus* for radiant energy, Salleron, Paris.

53. *Two Instruments for the Calibration* of mercurial thermometers, one by Golaz and the other by Salleron.

54. *Rowland's Apparatus for determining the mechanical Equivalent of Heat*, or for investigating the specific heat of liquids and their change with rise of temperature.

This instrument was constructed by the aid of funds contributed by the Rumford Committee of the American Academy of Arts and Sciences, but the instrument will remain for the present at Baltimore. It was constructed by Schneider. It is run by a petroleum engine, No. 66 below.

To be constructed soon:*

Apparatus for compressing gases to 1,000 atmospheres.

Apparatus for *accurately* determining the form of the adia..

* Nos. 18, 24, 25, and 27, and the silvered scale of No. 39, belong to Prof. Rowland, but are used in the laboratory.

batic curve of gases and vapors *at any temperature up to about* 100° C.

MISCELLANEOUS.

55. *Comparator*, by Meyerstein, for bars 1 meter long. Microscopes cannot be set nearer than 10 centimeters. One division of head of micrometer screws is about 1-700 millimeter.

56. *Microscope Comparator*, designed by Rowland after Rogers' plan, and made by Grunow.

57. *Dividing Engine*, by Perreaux. Free motion about 55 centimeters. Screw, ½ millimeter thread. Head divided into 250 parts. 5 1 divisions of head gives 1 millimeter almost exactly. Subsidiary screw at right angles to other one.

58. *Air Pumps.*—Rotary and common, by Ritchie, of Boston; mercury, on Jolly's plan, by Berberich, of Munich.

59. *Rotary Pump* for compressing gases to 15 atmospheres, Golaz, Paris.

60. *Three Mercury Gauges;* one about 25 meters high, and measuring pressures up to about 33 atmospheres; one movable and measuring pressure from 1 to 4 atmospheres; and one measuring from 0 to 1 atmosphere.

61. *Barometer*, by James Green, of New York, with very large tube.

62. *Two Cathetometers;* one by Meyerstein and the other by Salleron.

63. *Standard Meters*, compared at Washington.

64. *Balances and Weights.*—One balance weighing to 5 kilo. and accurate to about 1 mg., with weights from 5 kilo. to 1 mg. One weighing to 200 grms. accurate to about 0·1 mg. with weights from 100 gr. to 1 mg. These are by Schickert, of Dresden. One heavy balance weighing to about 25 kilo. and accurate to about 0·1 grm., by Schneider.

Standard glass kilogramme on Jolly's plan, and compared with Berlin standard. From Berberich, in Munich.

The first balance mentioned is mounted on top of a case, so that globes for weighing gases can be suspended beneath it.

65. *Clock-work* with Foucault's regulator for running small apparatus at a regular velocity.

66. *Petroleum Engine* of three-horse power. It is capable of giving a large amount of compressed air at more than 100 pounds to the square inch pressure, and might be used for repeating Thomson's and Joule's experiments, or any others on the flow of gases.

67. *Two Spherometers;* large by Meyerstein, and small by Salleron.

68. Several extra micrometer eye pieces.

69. *Apparatus for Researches on the Flow of Liquids.*—Greatest available head about 1·4 meters.

BIOLOGICAL LABORATORY.

In charge of Professor H. N. MARTIN.

Apparatus for Exact Measurements.

1. *Pendulum Myographion*, modified from Fisk's; available for the measurement and analysis of rapid movements. The instrument consists essentially of a pendulum carrying a glass plate at the bottom, swinging on friction rollers, and corrected for the latitude of Baltimore, so as to swing in one second. Behind the pendulum is a divided arc, and the amplitude of the swing can be varied from a few inches to four feet. In use an electro-magnet is moved along the divided circle, and then—the current being closed through it—the pendulum on being raised is held by it. On the other side is a catch, also movable along the arc. By turning a key at the side the current in the electro-magnet is broken, and the pendulum swings across, and is held by the catch on the other side. During its transit the movement to be analyzed is inscribed on the glass plate, which is previously smoked. Designed by A. G. Dewsmith, Esq., Trinity College, Cambridge, England. Made by Elliott, London.

2. A set of three pairs of König's recording tuning forks for measuring small periods of time; giving respectively 50, 100, and 200 double vibrations per second.

3. Bernstein's differential rheotome, with Helmholtz's electromoter to drive it. Zimmermann, Heidelberg.

4. Two Sir William Thomson's reflecting galvanometers; one large and the other small resistance. Elliott, London.

5. *Ludwig's Kymographion;* to give uniform horizontal movement to an endless sheet of paper, on which vertical movements can be recorded and subsequently measured and analyzed. The instrument is provided with an electro-magnetic chronograph. Made by Fulcher, Cambridge, England.

6. *Kymographion.*—Modification of the above. Made by Warden, Muirshead & Black, London.

7. "*Signal*" of Deprez. Electro-magnetic chronograph, recording up to 250 double vibrations per second.

8. *Chronograph* of Masey. Similar to above, recording to one-hundredth of a second.

9. *Spectroscope*, one prism, by Browning, London.

10. *Wild's Polaristrobometer.*—Schmidt & Haensch, Berlin.

11. *Completely fitted Microscope* by Zeiss, Jena. With microspectroscope and polarizing apparatus.

12. *Seconds Clock with Electric Attachment.* Elliott, London.

FRICTION OF FLUIDS.

AT a recent meeting of the London Physical Society, Earl Rosse in the chair, Prof. Unwin, of the college, read a paper on "Experiments Relating to the Friction of Fluids on Solid Surfaces against which they Rub." It has long been known that a board dragged through water suffers a resistance varying in some way as the square of the velocity; that a stream has a uniform motion at such a velocity that the component of the weight of the water down its inclined bed is balanced by the frictional drag on the bottom. The fluid in the neighborhood of the stream is known not to move as a solid mass, the center moving faster than the sides, and the different fluid layers rub against each other. The adhesion of the fluid to the solid, against which it moves, also gives rise to a sliding or shearing action. Our knowledge of the subject has hitherto been gained from observations on pipes, streams, and from the experiments of the late Mr. Froude with a plank of wood drawn through the water of a canal. It is desirable to have a set of laboratory experiments, however, as the conditions can be varied more than can be done by such methods, and for this purpose the author had designed a special apparatus. In Mr. Froude's experiments there was a practically unlimited mass of water and a definitely limited extent of solid surface; and his results are not free from certain anomalies. The author thought it might be instructive to try the other case of a limited mass of water, and a virtually unlimited surface; a disk in rotation gives such a surface. In some respects a cylinder would (as suggested by Prof. Ayrton) be the simplest to treat theoretically, but there are experimental difficulties in its way. The apparatus of the author consists of a metal disk rotated on a vertical axis in a vessel of water; and the problem is to determine its resistance to rotation, since this will be equivalent to the water friction upon it. Within the outer vessel is placed a thin copper chamber, the diameter of which is unalterable, but the depth is variable at pleasure. The disk is placed concentrically inside this chamber, where there are two cheese-shaped masses of water, one above and one below the disk, which are dragged into rotation next the disk and retarded next the sides of the pan. The couple required to rotate the disk is equal to the couple exerted by the disk or the fluid when the motion is uniform. Hence the tendency of the chamber to rotate is measured by suspending the latter from three wires in a manner similar to the bifilar suspension of magnets. An index marks whether it rotates or not on a graduated scale, and a weight suspended by a cord measures the force required to keep the index at zero. Let M be the moment of the fractional resistance of the disk; N the number of revolutions per second. Then $M=CN_x$, where C and x are constants. The author has obtained a number of results, which are, however, not yet ready for publication. He mentioned, however, that a rough cast-iron disk has a frictional resistance almost exactly as the square of the velocity; whereas a turned brass disk gave a value of x decidedly less than 2. The resistance is a little greater when the mass of water is larger. These results were calculated for a speed of 10 feet per second. The author hopes to try the effect of temperature, etc., on fluid friction, and viscous as well as thin fluids.

Pitch of Tuning Forks.—Lieut. G. S. Clark, R.E., explained the process invented by Prof. McLeod and himself for determining the absolute pitch of tuning forks. Unlike other methods, this is an optical one, and consists in arranging the tuning fork to vibrate in front of a rotating drum whose periphery is marked with dots or fine lines at equal intervals. A microscope was arranged to comprise in its field of view the edge of the fork and the several of the intervals on the drum, so that when the drum was rotated at a rate which made the speed of an interval equal to the period of the fork, a set of prominences or waves, in width equal to an interval, was visible, the body of the wave being caused by the advance and recession of the fork in its vibration. The rotation of the drum was regulated by an air regulator devised by Prof. Unwin, the observer himself quickening or slowing the drum so as to keep the prominences steady. The time was got by an electric clock designed by Prof. McLeod. An aniline glass pen was used to mark the beginning and end of the periods of observation on the drum. A counter was also employed to give the number of revolutions. The pen and counter were actuated by electricity through the medium of a key. In these experiments a König fork, giving 256 vibrations per second, correct at 16 1° C., was tested and found to give 256·2966 vibrations per second. Frequent bowing did not alter the phase. Fixing the fork rigidly, as in a vise, did so. The temperature coefficient for König's forks (0·00011 for each degree Centigrade) was confirmed by these experiments. Forks of different octaves were compared; audible beats could be counted; and modifications of Lesage's figures seen. This optical method is preferable to audible ones, because of its independence of the ear and the fact that nothing is attached to the fork itself.

Electric Clock.—Prof. McLeod then described an electric clock used in the foregoing experiments. A zinc and steel compensating pendulum moved by its own gravity; but at each beat made and broke a battery circuit by means of two bent springs, one on either side. The current passing through an electro-magnet detained a bent lever until the pendulum swung to the other contact. By this contrivance time was marked. Prof. McLeod found that the platinum contacts frequently stuck together in these experiments; but this defect had been cured by the use of a liquid shunt of dilute sulphuric acid, which destroyed the extra current. This remedy had been suggested to him by Lord Rayleigh. Prof. McLeod demonstrated the complete success of this device, which acts as well as a condenser shunt. He had also observed a curious effect with these liquid shunts, which as yet he could not explain. Two shunts, having the same acid in both, were employed, one shunting the extra current from four Daniell cells and one that from two Daniell cells. The first showed evolution of H and O gas, the platinum electrodes being unaffected. The second showed no evolution of gas, but one platinum plate was dissolved away and deposited in a black powder on the other. He also exhibited a new cell formed of zinc and mercury plates, with zincic iodide solution and mercurous chloride salt. Red iodide of mercury is formed at the negative electrode. The E.M.F. is seven-tenths of a Daniell cell, but the interval resistance very low and the cell very constant, while there is no local action.

Prof. Guthrie suggested that as the extra current was really a succession of sparks the platinum might be carried bodily over from one electrode to the other.

Mr. F. H. Varley stated that Mr. F Higgins had observed a similar effect with carbon electrodes in a voltameter, one carbon falling away into a fine powder, and due perhaps to the disintegrating action of liberated gases. He had also himself seen a platinum wire in contact with a carbon one eaten thin and drawn into very fine silky pens, while the carbon was stained blue, although the current passing was of low tension.

Mr. Chandler Roberts suggested that perhaps a hydride of platinum was formed in the case mentioned by Prof. McLeod.

Prof. Guthrie suggested experiments with fluorescent liquid shunts in the dark.

LAVOISIER'S CABINET.

M. DUMAS, of the French Academy of Sciences, has been informed by M. Truchot that the chemical laboratory and physical cabinet of Lavoisier have been reverently preserved by his family, and are now in the possession of M. E. De Chazelles, at Caniére, near Aigueperse, Puy de Dome. The smallest of the three balances employed by him is sensitive to the 1-612th of a grain. Unfortunately, the weights belonging to these balances are missing; but the kilogramme and its subdivisions as established by Fortin yet remain, recalling the fact that Lavoisier had made all the determinations necessary for fixing the weight of the kilogramme. He is known to have made a comparison of the heat produced by converging lenses and that of the blowpipe supplied with oxygen; and among the collection of what may be called his experimental relics there are many precious stones, some of which had evidently been subjected to the action of a very high temperature.

[Continued from SUPPLEMENT No. 188.]

AMERICAN ENGINEERING.—III.*

THE ILLINOIS AND ST. LOUIS BRIDGE.

JAMES B. EADS, Chief Engineer.

THE supporting members of the superstructure consist of twenty-four steel arches, eight in each span. Each arch is composed of a large number of straight tubes, with slightly beveled ends, and to the casual observer appears to be a continuous curved tube. The arches are arranged in four ribs, each rib consisting of an upper and lower member connected by a system of wrought iron diagonal bracing. The axes of the upper and lower members form parallel curves twelve feet apart. Each span has four ribs. The whole number of tubes is 1,056. A tube is about twelve feet long, and comprises a steel envelope ¼ inch thick, and 6 rolled steel staves, varying in thickness from 2¼ inches at the springing to 1¼ inches at the crown. The exterior diameter is always 18 inches. Steel or wrought iron sleeve couplings firmly unite the tubes by means of parallel grooves turned on the ends of the staves. Steel pins through the couplings and staves receive the ends of the main brace bars. Each main brace consists of two heavy rolled iron bars, about two feet apart, with T bars and lattice bracing between. The two lowest tubes of each member are screwed into heavy wrought iron skewbacks which rest on cast iron bed plates, and by long steel or iron bolts are anchored to the masonry. All these bolts are 5½ inches in diameter, and from 22 to 36 feet in length. In the channel piers the bolts pass through the masonry and unite the two skewbacks. About 2,200 tons of steel and 3,400 tons of iron are used in the whole bridge.

The length of the West span is 504·07 feet, of the East span 504·84 feet, and the center span 522·39 feet, measured on a line through the centers of the lower skewback pins.

The roadways of the bridge are carried by vertical struts made of braced iron channel bars resting directly upon both ends of the steel pins already mentioned. The upper roadway is 54 feet wide.

The bracing between adjacent ribs consists of tubular iron struts screwed to the ends of the steel pins, and diagonal steel tension rods. The diagonals are in horizontal and vertical systems. The vertical system serves to distribute live loads from rib to rib, and renders it possible by screwing up the ties to throw the entire weight of one rib upon the others, and take the rib to pieces; a tube injured during erection was taken out after the entire span had been completed, and a new tube was inserted. Each pair of ribs supports a railroad track. To increase the lateral stability a horizontal wind truss the full width of the bridge extends across each span immediately below the upper roadway. It is a lattice girder made wholly of iron. The chords of each truss are united at the piers and rest upon the channeled surface of a cast iron block which is fixed in position by large wrought iron bolts running to the right and left and deep into the solid masonry.

All the anchor bolts and sleeve couplings were tested; the steel bolts to 40,000 lb. per square inch, the iron ones to 18,000 lb. per square inch. A large proportion of the staves were subjected to an actual compression of from 50,000 to 60,000 lb. per square inch. Specimen bars of all the material used were tested in great numbers and records kept. Over thirty model steel tubes and hundreds of steel cylinders from American and European manufacturers were tested in the investigations.

The public test of the bridge consisted in placing fourteen locomotives simultaneously upon the tracks of a single span.

The arches were erected by building the ribs out from the skewbacks, partly self supported, but mainly held by iron cables passing over towers built on the tops of the piers. All the adjustments were made with the greatest accuracy, and the arches were all closed in the centers of the spans by the use of "extension" tubes, capable of being lengthened or shortened by means of solid wrought iron cylinders filling the interior of tubes and furnished with right and left handed screws. The contract of making and erecting the superstructure was taken by the Keystone Bridge Company of Pittsburg, Pennsylvania. Great difficulty was experienced in obtaining steel and iron of the required shape and strength, but in spite of every unforeseen trouble, every part of the plan was faithfully executed.

In giving to the Chief Engineer, Capt. James B. Eads, the pre-eminent place as the designer and controlling spirit of the enterprise, we must not fail to mention the eminent services of his assistants, Col. Henry Flad and Mr. Charles Pfeifer.

The bridge was publicly opened on July 4, 1874. The cost of the bridge, including a large amount of interest and commission accounts, was not far from $10,000,000.

A full account of the Illinois and St. Louis bridge, by Professor C. M. Woodward, of St. Louis, is nearly ready for the press, from which the above account, as well as that of the foundations, has been taken. The work has been undertaken at the request of Capt. Eads, and all questions of fact will be indorsed by him. The history of the bridge will include the organization of the company, description of the work at all stages, difficulties met, preliminary tests, and tests of working pieces, process of erection, theory of the arch, and the calculations. It will be illustrated by fifty or sixty large plates and numerous small cuts.

GIRARD AVENUE BRIDGE, PHILADELPHIA.

Designed by CLARKE, REEVES & Co.

There are seven lines of trusses or girders placed side by side, 16 feet apart, and united by horizontal and vertical bracing.

These trusses are of the double Pratt system. The upper compressive members and the vertical posts are Phœnix flanged columns, united by cast-iron joint boxes. The lower chords and diagonals are weldless eye-bars, die forged by hydraulic pressure. Upon the top of the posts, 12 feet apart, are laid heavy 15-inch rolled beams, and upon these longitudinally, 9-inch beams placed 2 feet 8 inches apart; these are covered transversely with rolled corrugated plates ¼ inch thick, corrugated 1¼ inch high by 5 inches wide; these form an unbroken iron platform upon which the asphalt concrete is placed.

The dead load of the structure with a moving load of 100 pounds per square foot makes a total of 30,000 pounds per lineal foot, carried by seven trusses.

The limit of strain is 10,000 pounds per square inch, reduced to 6,000 pounds per square inch as the compressive limit on parts. All points of contact are either planed or turned. The pins are of cold-rolled iron, and the limit of error between pin and hole is one sixty-fourth of an inch.

The iron used in this bridge is double refined, capable of

* American Engineering as illustrated by the American Society of Civil Engineers at the Paris Exhibition of 1878. Compiled by George S. Morrison, Edward P. North, and John Bogart, Committee, Transactions of the Amer. Soc. of Civil Engineers.

bearing the following tests: ultimate strength, 55,000 pounds to 60,000 pounds per square inch; no permanent set under 27,000 pounds to 30,000 pounds per square inch; average reduction of area at point of fracture 25 per cent. The elongation of a 12-inch bar is 15 per cent., and the cold bend of a 1¼-inch round bar before cracking, 180°, or hammered flat.

The floor is made of corrugated iron plates covered by 4 inches to 5 inches of asphalt, making a water-tight surface. The 100 feet of width is divided into 67½ feet of carriageway, and two 16½ foot sidewalks. The roadway is paved with granite blocks in the usual manner, except that it is divided into seven ways by two lines of iron trackways next the sidewalks for horse cars, and five lines of carriage tramways, made of cut granite blocks 1 foot wide, laid to a 5-foot gauge. The gutters and curbstones are of fine cut granite. The sidewalks are covered for 10 feet of their width with black Lehigh County slate tiles, 2 feet square, laid diagonally. On each side of the tiles are spaces 2 feet wide, which were originally laid with encaustic tiles. After one winter's frost, these tiles became so much shattered that they were removed and white marble tiles substituted in their place. The curbstone, 18 inches wide, makes up the remainder of the 16½ feet.

The sidewalks are separated from the roadway by railings of galvanized iron tubes with bronze ornaments, and are supported by cast-iron standards at every 6 feet. Every eighth standard is prolonged into a lamp post. There are eight refuge bays, each of which contains a cluster of six lamps, the supporting shaft rising through an octagonal seat, which forms its base. The outer balustrade and cornice is of cast-iron with bronze open work panels, and treated in a highly ornamental manner.

The construction of the permanent new bridge began May 11th, 1878, and July 4th, 1874, it was formally opened for public travel.

[For detailed drawings see SCIENTIFIC AMERICAN SUPPLEMENT, Vol. 1, 1876.]

BRIDGE AT PORT JERVIS, N. Y., OVER DELAWARE RIVER,

GEORGE S. MORISON, Engineer.

The bridge was destroyed at 7.40 A.M., March 17, 1875. It was a double track iron bridge of five spans, one through span over the Delaware and Hudson Canal, and four deck spans over the Delaware River. The span over the canal was undisturbed. The ice lifted the four river spans from the piers, leaving the masonry uninjured. The East span settled down on the ice, remaining within a few feet of its proper position; the other three were carried down the river on the floating ice and left at various points from four to twelve miles below. The West span was 160 feet long in the clear, the others each 150 feet, the rail being about 50 feet above the ordinary stage of water.

The work of reconstruction was begun at once, and a temporary bridge, consisting of two spans of trestle and two of Howe truss, was ready for use on Saturday, March 27th. The plan for a new permanent structure was determined on and proposals received on the day of the disaster, and a contract was made with the Watson Manufacturing Company, of Paterson, N. J., to build the new bridge by the pound. The plans were virtually completed and the bills of material were on the way to the rolling mills on the 18th.

The first span, 166 feet over all, was entirely shipped on Saturday, April 3d, and swung Wednesday, April 7th.

The second span, 156 feet over all, was swung Monday, April 12th.

The third span was swung Saturday, April 17th.

The fourth span was swung Monday, April 19th.

The permanent floor could not be put on till Sunday, April 25th, and on the following day the double track was completed, precisely 40 days after the destruction of the old bridge, the new iron bridge having been manufactured in 30 days, and erected in 32 days from the date of the contract.

The long span weighs 304,422 pounds, and the others averaged 265,641 pounds, making a total of 1,101,345 pounds, besides cast iron bed plates.

IRON RAILROAD BRIDGE OVER THE OHIO RIVER, AT LOUISVILLE, KY.

ALBERT FINK, Chief Engineer. F. W. VAUGHAN, Assistant Engineer.

This bridge crosses the Ohio River at Louisville, connecting the States of Kentucky and Indiana. Its total length is 5,294 feet, consisting of twenty-seven spans, of various lengths from 50 to 250 feet, on the Fink plan, placed below the grade of the road, and 2 channel spans, one 370, the other 400 feet long, placed above the grade of the road. This bridge was commenced in the fall of 1867, and completed in the spring of 1870. The channel spans are of a peculiar design, a modification of the triangular plan of bracing—by introducing auxiliary trusses between the main braces. The feet of the main braces are 56 feet 7¼ inches apart, and by the auxiliary trusses this space is divided into four parts, giving a support to the stringers upon which the track rests every 14 feet 1¾ inches. The height of the truss is 46 feet. Each side of the bridge consists of two separate trusses, which are simply bolted together. The chords are of cast iron, the braces having to resist compression of wrought iron, and the tension members also of wrought iron.

The following is a statement of the quantity of iron in some of the principal spans:

	Cast Iron.	Wrought Iron.	Total.
400 foot span.	570,585 lb.	834,880 lb.	1,405,465 lb.
370 " "	480,953 "	640,095 "	1,121,048 "
245¼ " "	216,119 "	215,803 "	431,922 "
180 " "	126,308 "	91,259 "	214,667 "
150 " "	101,453 "	70,224 "	171,677 "
100 " "	58,725 "	29,183 "	87,908 "
50 " "	7,557 "	15,801 "	23,358 "

ROCK ISLAND DRAW BRIDGE.

Designed and built by C. SHALER SMITH, C. E.

The Rock Island Bridge crosses the Mississippi River, connecting the cities of Davenport, Iowa, and Rock Island, Illinois. It was built for the United States Government in 1871, and accommodates the highway travel on the lower floor, and the railway service on the middle deck. The pivot span is 368 feet in length; weighs, above the rollers, 1,505,000 pounds, and has two floors, respectively 37 and 23 feet wide. This great wind surface, combined with the weight (the entire rotating mass weighs 1,564,000 pounds), and the fact that one end of the span is under the lee of the United States Depot Arsenal, and that the bridge is exposed to heavy wind storms, which, when blowing from the northeast, east, or southeast, act on only one end of the span, made the designing of a suitable turn-table a matter of the utmost importance. A cast iron circular girder, 30 feet in diameter, 5 feet in depth, web 2 inches thick, and flanges 15 inches wide, rests upon a live ring composed of 34 wheels, each 30 inches in diameter and 14 inches face. The traveling weight borne by each of these wheels is 44,250 pounds. To secure perfection of action, a revolving frame, the full size of the circular girder, was first constructed at the machine shop where the turn-table was built, and on this the girder and wheel track were planed to an exact level. The wheels were all turned to a gauge, and the entire table fitted together on the revolving frame, so as to test the fitting of every part.

The span is rotated by two hydraulic rams, each of 10 feet stroke and 5 inches diameter of piston. These are placed over the circular girder, one on each side of the span, in a vertical position, and are worked by a double cylinder engine, each cylinder being 6×8 inches. The force pumps are four in number, each with 1½ inch piston. The rams are reciprocal, each being the reservoir for the other, and the office of the pump is to transfer the liquid from one ram to the other. Both rams are thus under the same pressure at all times, and hold the span in equilibrium, except while the pumps are shifting the fluid from right to left, or *vice versa*. Owing to the very low temperature at which the span is often required to be moved, a non-freezing liquid was necessary in order to operate the rams. A mixture of glycerine and water—fifty per cent. of each—was found to be the best for this purpose. The power of the rams is transferred to the pier by means of a wire rope, 1½ inches diameter, arranged as in an Armstrong crane. The frictional resistance to rotation at the center of the live ring wheels is 7·36 pounds per 1,000 pounds of superincumbent weight.

The pivot span supported by this turn-table is peculiar in that it is proportioned without dead weight reactions under the end supports, that the top chord is composed entirely of eye-bars, that every panel point in both chords is hinged vertically, and that all lateral connections are hinged horizontally.

KENTUCKY RIVER BRIDGE, CINCINNATI SOUTHERN RAILROAD.

Designed and built by C. SHALER SMITH, C.E.

This bridge crosses the cañon of the Kentucky River, 112 miles south of Cincinnati, at an elevation of 275 feet above the low water level of the river. The six photographic views show the mode of erection of the structure at its various stages, and the drawings appended portray the typical parts of the truss and piers. The peculiarities of the truss are as follows: The middle portion is a continuous girder 525 feet long, supported by piers placed 375 feet apart, and supporting two discontinuous spans, each 300 feet in length, at the ends of projecting cantilevers extending 75 feet from each pier. The upper and lower chords are riveted throughout, except at the cantilever points, where the upper chord is hinged and the lower chord fitted with sliding tenons, so that motion from load or thermal changes may be uninterrupted. All connections of the web members to the chords are hinged. The piers are composed of four legs each, and are given a base sufficient to prevent tension on the leeward legs under any condition of load or violence of wind. For convenience during erection, and to accommodate thermal changes, each pier pedestal is placed on a double set of friction rollers, so as to admit of motion in any horizontal direction. The connection between span and pier consists of a pin 12" in diameter, thus making a fixed joint and permitting a rocking motion only. The piers were placed 375 feet apart when the thermometer was at 60°, and are perfectly vertical only at this temperature. The additional strains caused by the expansion of the truss and momentum of a train weighing 1,100 tons, and supposed to be brought to a rest on the bridge after entering it at 30 miles per hour, have been computed, and the necessary extra material added to the legs and braces to resist them. At the hinging points both web systems are united in one, in order to avoid any ambiguity of strains; and to render this more exact, the union is effected by means of a hinged link placed at the angle of the resultant between the tie bars of both systems. The action of spans, piers, and hinges, under loads and during changes of temperature, leaves nothing to be desired, and the novelties in construction and mode of erection proved to be practical successes. [For drawings and illustrations see SCIENTIFIC AMERICAN SUPPLEMENT, Vol. 4, 1877.]

BRIDGE OVER THE PENNSYLVANIA RAILROAD AT FORTY-FIRST STREET, PHILADELPHIA, PENN.

WILSON BROS. & Co., Engineers.

The superstructure of this bridge is constructed on a stiffened triangular truss system, entirely of wrought iron. It has two trusses with outside sidewalks, and an ornamental finish at the entrances of cast and galvanized iron fastened to the wrought iron framework. The floor beams are of wrought iron, suspended built beams, placed across from truss to truss at the panel points. Upon these rest longitudinal floor joists of white pine. The roadway and sidewalks are of double thicknesses, the sub-flooring for each being of two-inch white pine, the top flooring for the roadway of three inch white oak, and that for the sidewalks of one and a half inch yellow pine, tongued and grooved and dressed on the upper surface. The upper chords of the trusses and the vertical posts are formed of rolled plates and angles, and the lower chords and inclined ties of link bars, with pin connections throughout.

The principal dimensions are as follows:

Span, center to center of end lower chord pins	318 ft. 4 inches.
Height of truss, center to center of chord pins	21 " 4 "
Number of main panels, ten.	
Number of sub-panels, twenty.	
Distance between trusses, center to center	40 ft. 0 inches.
Distance, center of truss to center of hand-railing	10 " 0 "
Entire width of bridge, center to center of handrailing	60 " 0 "
Clear span between masonry on the square	185 " 9 7/32 "
Clear span between masonry on the askew	209 " 3 "
Angle of askew	62° 35' 47"

CINCINNATI SOUTHERN RAILWAY BRIDGE OVER THE OHIO RIVER AT CINCINNATI.

Built by Keystone Bridge Co., J. H. LINVILLE, C.E., Pres.

The portion of this bridge constructed by the Keystone Bridge Company, under their contract dated February 24th, 1875, embraced the southern abutment and piers numbers 1 to 6 inclusive, and the superstructure for the following spans, viz.:

One deck span	110 feet.
One pivot span	370 "
One channel span	519 "
Two through spans	300 "

Making a total length of 1,599 feet, measured from center to center of piers.

The general data are as follows:

	Span 1.	Span 2.	Span 3.	Sp... 4.	Span 5.	Total.
Length, center to center, piers	110'	370'	519'	300'	300'	1,599'
" " " pins	108' 0 11/32"	365' 4"	515'	295' 1"	295' 4"	
Depth, " " chords	15' 6"	36' 6"	51' 6"	37'	37'	
Width, " " trusses	10' 0"	15' 6"	20' 0"	15' 10"	15' 10"	
Weight of iron.....pounds	104,400	826,500	2,634,400	657,400	657,400	

Masonry for spans, 1 to 5 inclusive	12,621 cubic yds.
Concrete	500 " "

The contract price was $663,570 with a provision for contingencies, which increased the entire cost to about $700,000.

The designs for the superstructure were submitted by J. H. Linville, C.E., President of the Keystone Bridge Company, and embraced his latest improvements. These plans were slightly modified by the engineer of the railway company, the work being constructed under his supervision and subjected to his approval.

The lower chords are placed at an elevation of 43·25 feet above high water and 105·65 above low water.

The trusses of the channel span are trapezoidal, consisting of 20 equal subdivisions or panels, with vertical intermediate posts, and inclined end posts, the tension diagonals reaching two panels, and being inclined at an angle of 45 degrees.

The lower chords have rectangular ends, and are packed closely together, forming a flat bearing on their upper surface for the bases of the posts, and a recessed bearing on under side to receive the suspended floor girders and resist the action of the lower lateral ties.

To give greater width of truss, twin rectangular posts were used, stiffened at the middle of the height by longitudinal struts extending, between posts, from end to end of the trusses. At the intersection of these struts with the posts transverse struts and diagonal ties were introduced to serve as wind bracing, and maintain the lateral stability of the trusses.

Floor girders are four lines of stringers, of wrought iron built beams, which support the long wooden ties and guards.

The bridge is designed to sustain, in addition to its dead weight, the following rolling load, at a speed of 30 miles per hour, viz., two locomotives coupled, each weighing 36 tons, on drivers in space of 12 feet, total weight of engine and tender loaded 66 tons, in space of 50 feet, and followed by loaded cars, weighing 20 tons, in 22 feet. An addition of 10 to 30 per cent. is added to the strains produced by the rolling load (considered as static) in the calculation of floor beams, stringers, suspension links, counter rods, and all other parts of the bridge liable to be strained suddenly by the passage of a rapidly moving load.

Wind pressure of 50 pounds per square foot is provided for.

Tensile strains were limited to 10,000 pounds per square inch on best double refined iron. Strain of compression in large rectangular chords to 8,000 pounds per square inch. And on posts the strains were limited to 6,000 pounds per square inch.

The bridge was constructed at the shops of the Keystone Bridge Company, Pittsburg, and erected on trestling consisting of three tiers of lower scaffolding and two tiers of upper falseworks. It required the labor of 60 men 24½ days to raise the iron work and put it in place preparatory to swinging the trusses clear of the scaffolding.

All the iron used in the structure was tested by specimens. Special forms of joints were tested to breaking to determine their proportions, and all lower chords and suspension bars were tested to 20,000 pounds per square inch.

The channel span was subjected to a test load of seven locomotives coupled and four flat cars—weight, 966,000 pounds. The maximum deflection was 2 7/16 inches. [For detailed drawings see SCIENTIFIC AMERICAN SUPPLEMENT, Vol. 3, 1877.]

POINT BRIDGE, PITTSBURG, PA.

Point Bridge was designed by Edward Hemberle, Engineer of the American Bridge Company. It consists of tower and chains, with platform suspended therefrom in the same manner as in a regular chain suspension bridge. To this is added a stiffening system above the chains, and rigid posts arranged between chains and platform so as to prevent the roadway from undulating or oscillating independently of the structure above. The stiffening appliances above the chains consist of rigid chords running in straight lines from the top of the tower toward the center of the chain, and connecting thereto by a hinged joint at each end. Between these chords and the chains there is a system of bracing, composed of posts and diagonal tie-rods, all connections being pin-jointed. The chain, being a catenary, or curve of equilibrium, bears all the permanent load of the structure without straining the stiffening trusses. This object was accomplished by erecting the bridge completely before connecting the ends of the straight top chords to the center

joint. The rods are provided with turn-buckles, and are so adjusted as to be strained under moving loads only.

The total length of the bridge is 1,245 feet from back to back of anchorages, with one middle span of 800 feet between centers of piers, and one independent trussed side span of 145 feet in length at each shore. The roadway rises from both shores toward the center of the channel, with grades not exceeding 3½ feet in 100—the highest point of the roadway being 83 feet above low water. The saddles upon which the chains rest on top of the towers are 180 feet above low water. The deflection of the chain is 88 feet, which is considerably more than is usual for suspension bridges, but the stiffening allows of increasing the deflection and thereby reducing the strains in the chains as well as their weight. The bridge is 34 feet wide from center to center of outside railings, and this space is divided into a roadway 21 feet wide and two sidewalks of 6½ feet each. [For drawings see SCIENTIFIC AMERICAN SUPPLEMENT, Vol. 2, 1876.]

IRON DERRICKS USED BY THE PASSAIC ROLLING MILL COMPANY, OF PATERSON, N. J., IN ERECTION OF THE NEW YORK ELEVATED RAILROAD.

These derricks were designed by Mr. Watts Cook, president of the company. The smaller one consists of two trucks, one carrying an iron hoisting frame and the second a hoisting engine; the two trucks are coupled together, and in use their wheels rest on the girders already placed in position; the forward arm of the hoisting frame reaches to the center of the span to be erected, while the rear arm is anchored down; with this derrick a gang of twelve men have erected 210 tons of iron in ten hours. The larger derrick has but one truck, which runs on rollers instead of wheels, the power being placed at the center of the frame, which is 108 feet long and has a reach of 50 feet.

GRAVITY RAILROADS.

THE New York, Lake Erie and Western Railway Company have completed arrangements by which they will not only be placed in direct passenger connection between New York and the Pennsylvania coal regions, but will be able to present to the public one of the most novel and delightful excursion routes in the country. One section of the Erie extends to Honesdale, Penn. Honesdale is the head of the Delaware and Hudson canal, and is 135 miles from New York. Between Honesdale and Carbondale extends what is known as the Delaware and Hudson Canal Company's gravity road. Between Hawley—125 miles from New York—and Dunmore, a suburb of Scranton, the Pennsylvania Coal Company's gravity road extends a distance of 33 miles. An account of these novel roads and the magnificent scenery through which they pass was recently given in letters to the *Daily Advertiser*, and the following description from the New York *Times* gives additional details of interest:

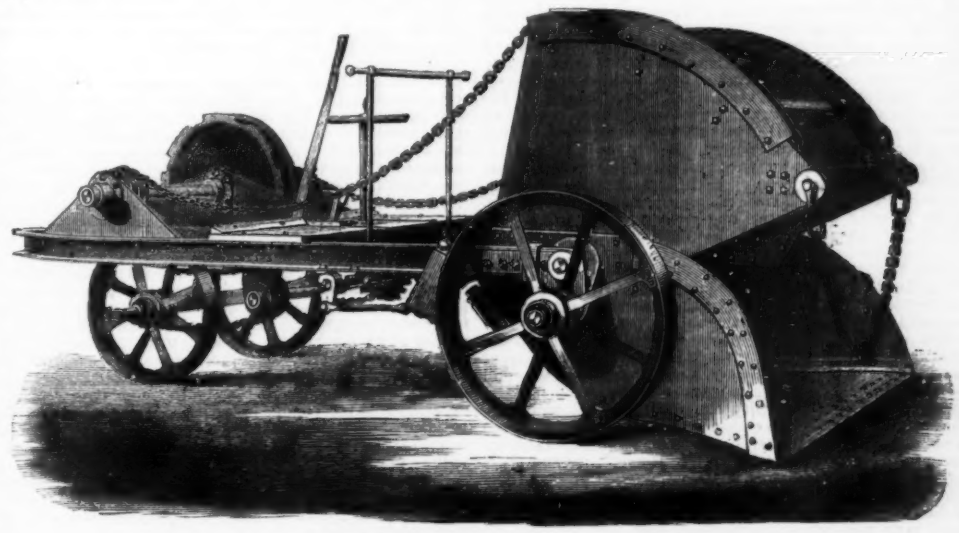
The traveler who enters one of these novel little cars at Honesdale for the first time will be surprised and puzzled at what he sees. The car is nicely upholstered, but it is not more than half the size of an ordinary passenger car. It moves out from the covered depot a few yards and stops. The traveler looks out and sees the track leading straight ahead, but directly up the side of a hill, at an angle of about sixty degrees. There is no locomotive anywhere in sight, and the top of the hill is nearly a quarter of a mile away. A train hand stands on the front platform. He holds in his hand a heavy chain, with an immense hook at each end. A large iron cable, resting on iron pulleys between the rails, extends from the foot of the plane to the summit. Suddenly the brakeman inserts one of the hooks in a sling attached to the car, and the other one in a sling on the endless cable. Another man pulls shortly three times on a wire that, suspended by rings on wooden posts, runs up the hill at the side of the track. Almost instantly the car starts, and makes up the hill at the rate of fifteen miles an hour. There is no visible motive power. The car is drawn up the hill by a stationary engine at the summit or head of the plane, by means of the endless wire rope, which winds and unwinds from huge iron drums. These engines are most elaborate and powerful machines, and are reversible in movement like a locomotive. After reaching the summit of the plane just described, the car runs on a descending grade of about fifty feet to the mile by its own gravity for four miles. Then another plane is ascended. Between Honesdale and the summit of the Moosic mountains, ten miles, eight planes are raised, and then the traveler is 2,000 feet above the sea. From this point he looks down on a landscape that extends to the east and south for over sixty miles, the Catskill mountains being plainly seen as the furthest boundary.

From the summit plane to Carbondale is seven miles, over an uninterrupted decline. It is impossible to imagine the intricate curves and windings the road makes in its course. The flight of the train down the mountain, sometimes rushing along at the rate of a mile a minute, is a most exhilarating and thrilling experience. The "runner," as the brakeman is called, stands on the platform of the front car, with his hand on the brake, and controls every movement of the train. He can send it along at the speed of the wind, or bring it to a stand-still at his will. No smoke, no cinders, no dust, annoy the tourist. Only the freshest of mountain air, of which the open cars permit the fullest enjoyment, and the most charming and varied of scenery. At one point on the down-mountain side the road brings the tourist within a mile of Carbondale. The city lies 800 feet below, in the valley, and a stranger might imagine that he was about to rush down into the city. But suddenly the train dashes around an abrupt curve, and goes thundering in another direction along the face of the mountain, and the city disappears. The road runs five miles around to make its entrance into Carbondale. Two miles from the city the tourist will see a track running parallel with the one he is riding on. It is fifteen feet away, and twenty feet below him. The universal impression is that this is a different road. This point, however, is the remarkable curve known as "The Shepherd's Crook." In order to get around certain obstructions the engineers were obliged to lay the road out on a curve so abrupt that it assumes exactly the shape of a shepherd's crook. This is a most puzzling thing to strangers—one moment riding on a track from which they see another far below them; the next dashing along on the lower track and looking upward at the one they have just left. The scene at Shepherd's Crook is one of awful grandeur. The road crosses a gorge, at the bottom of which, and 400 feet below, is the Lackawanna river. The gorge is a wilderness of primitive pine and hemlock trees, the tops of the highest of which are far below the train. In among the hemlocks a mountain stream tumbles down the mountain in a series of cataracts 300 feet in height. The Lackawanna valley, with Carbondale and other mining places, is spread out below for miles and miles. It has been arranged for excursion trains to stop on the summit of Shepherd's Crook, to enable tourists to fully take in all the beauties of this grandest of scenery.

At Carbondale connection is made with the Delaware and Hudson Canal Coal Company's locomotive road for Scranton and all points in the coal regions. The gravity roads have a "light" and a "loaded" track. That is, the loaded track is the one which carries the coal from the mines to the shipping places; the light track is the one on which the empty cars are carried back after new cargoes. The two roads traverse different routes to accommodate themselves to the grades and planes necessary. The Delaware and Hudson's gravity road from Carbondale to Honesdale carries the tourist up the Moosic mountain from Carbondale by eight successive planes. Then, to reach the level of Honesdale, it descends four planes, and what is call a "10-mile level," on ten miles of track over which the cars run by their own gravity. In descending planes the cars are attached to an endless wire rope, the same as in ascending. Their speed is regulated by an immense fan at the head of the plane, the atmospheric resistance, as the fan revolves, being sufficient to control the descent of the cars to the foot of the planes. The scenery on the loaded track of the gravity road is of neverceasing attractiveness. The Pennsylvania Coal Company's gravity railroad was constructed in 1854. It extends, really, from Pittston, Penn., to Hawley, but it is used only as far as Dunmore for passenger traffic. The scenery on this road is wilder and more rugged than on the Honesdale road. It extends almost its entire distance through a magnificent forest, clearings and pastoral scenes being rare. Massive rock-cuts, grand waterfalls, lakes as clear as crystal, weird gorges, and beetling cliffs break on the sight at every turn. Both the light and loaded tracks are thirty-three miles in length. There are nine planes to ascend on the trip from Hawley to Dunmore, and several long levels. The road passes Dunmore at a great height above it, runs on two miles, and "switches back" into the village. From Dunmore to Hawley the road climbs to an elevation of 2,100 feet in a distance of five miles. From that eminence the view is grand beyond description. There are six planes to ascend on the trip from Dunmore to Hawley, an uninterrupted run of fourteen miles, a plane to descend, then another run of fourteen miles to Hawley. The cars fairly fly along these levels, and the road is continually embowered by the forest trees. Both the Pennsylvania Coal Company's and the Canal Company's gravity roads are worked on the same system, and everything moves along like clockwork. Such a thing as an accident is so rare that it is hard for any one to remember when one has happened on either road.—*Boston Advertiser.*

IMPROVED STEAM SCOOP.

THIS scoop is intended for excavating large quantities of soil. It is being employed in Australia with great success, sinking excavations or "dams" as much as 24 feet deep in the beds of rivers for the purpose of holding water during the dry season.



IMPROVED STEAM SCOOP.

The merit of the invention of the scoop is mainly due to Mr. Peter Waite, who, finding it impossible by manual labor, or use of bullocks, to get down to any great depth, or within any reasonable time, so as to utilize the large extent of dry country in the Paratoo Run, early in 1875 turned his attention to the application of steam power in the forming of deep artificial water holes. Visiting England, he, in conjunction with Messrs. John Fowler & Co., devised the steam scoop, which, after some modification, has now reached a very high state of perfection. The ground is first plowed over by a powerful balance plow, which is followed by the scoop, which, being drawn forward, becomes filled with earth. The scoop is then raised, and the implement with its load is hauled to a suitable place, and its contents tipped. Two 16-horse power engines are employed, one on each bank. The scoop is bell-mouthed, 7 feet 6 inches wide at the mouth, but is 6 feet broad at the narrowest part, 6 feet from back to front, and about 4 feet deep at the shallowest part. When fairly full it holds about 2½ cubic yards of earth. The removal by plow and scoop of from 1,500 to 2,000 yards of stuff is considered a fair week's work, but with long hours 3,000 yards can be reached in the same time. The steam engines being placed on the banks, a wire rope is attached to each end of the plow, which is drawn backward and forward in the bottom of the dam, tearing up to a depth of, say 10 inches to 12 inches the most obstinate clay. The plow having completed its loosening work, the scoop takes its place, drawn forward by the one engine into the loose clay lying at the bottom of the dam. It is when full drawn back up the same side of the excavation by the other engine, and there at a suitable distance it, by an ingenious arrangement, empties itself and spreads its stuff as it is discharging. The cost of excavating a dam to 12 feet by the old process was 10d. to 1s. a cubic yard. The steam plow and scoop, when in fair working order, go to a depth of 24 feet at a cost of 6d. a cubic yard.—*The Engineer.*

THE CHATHAM FIELD OPERATIONS.

JUNE 27th was the final day of the Chatham siege operations of the year. For some weeks past the operations, which have consisted in an attack on works of field profile on the hill above Upnor Castle, have been pushed on. Captain Shepherd, R.E., has had charge of the defense, which has been conducted in the usual way, the defenders only receiving from the umpires such information as would have become known to them on active service. The attack has been directed against the fronts extending along the more gradual slopes of the hill. There have been a few new features exhibited. The most notable is the employment of the Prussian deep sap. It has been found in operations conducted by the German army that a sap roller was liable to be destroyed very suddenly by the defenders long after their artillery fire proper was silenced, by the sudden bringing into action of a wall piece or mitrailleuse, which, unlike a gun, requires no provision for recoil, and can be perched almost anywhere. Hence it has been recommended that the besiegers should dispense with the use of sap rollers and gabions by digging sufficiently deep into the ground to keep the working party protected by the depth of the cut in the ground, with the additional assistance of sand bags always kept supplied freely, and piled up more thickly if called for by the stress of a heavy fire brought to bear on the head of the sap. This deep digging is of course slower work than that which was assisted by gabions forming the foundation of a parapet. When directed straight towards the work the old sap is now replaced by deep cube sap, which consists of trenches from 4 ft. to 5 ft. deep and 2 ft. to 3 ft. wide, dividing into branches, cut so as to leave a solid square block of earth in the center, no gabions being employed anywhere unless specially required at any point. The whole of the siege trenches are this year unusually deep. There is an advantage in this as regards cover—in fact the besiegers on this occasion were quite unable to tell where the men were strongly posted, and even when making a sortie they could not often tell how far back they had driven their foe. On the other hand, in our opinion it is an evil to have the parapet larger than necessary, because the enemy in any sally find admirable cover. On this day they appeared to find the sand bag loopholes a most convenient height to fire through. The attacking party in fact stood on the level of the natural ground to fire through their sand bag loopholes. There was, therefore, nothing to make them less suitable to the enemy who seized the trenches, except the fact that the slope of the earth was less abrupt on their side. How very suitable these loopholes actually were to the enemy, when they made a sortie, was apparent from the instant way that all their rifles came through them when they reached the line of trench. In short, while deep trenching has real advantages for a sap, it is easy to see that it has also its disadvantages in a long line of trench, such as a parallel which may be turned by a strong sortie. The actual parallel trenches were not said to be deeper than regulation, but appeared to us to be decidedly deeper than we have ever seen them before. The operations of the day were as follows: The besieged army was supposed to be pressed by want of provisions, and made a strong sortie to force their way out, being so far successful that the besiegers were pushed back to the 1st parallel, abandoning their trenches. A re-enforcement arriving at this moment with artillery, turned the tide of battle and drove the garrison back into their works, when the besieging army followed them up carrying their outer line of defense. Two mines were sprung during the operations, the garrison finally blowing away a portion of the parapet on the salient attacked, which was supposed to be carried out while the enemy were on it. On the whole, the operations, which were not so extensive as on the special occasions when we have previously reported on them, were not so well carried out, and with the exception of the deep sap there was nothing to be seen on Friday of a novel character. The troops who made the sortie showed no signs of trying to force the lines at any particular point, but distributed themselves along the trenches destroying the besiegers' works. Nor did they cling to cover, as they should have done, but knelt down and came into line in the open, midway between two trenches, which were, perhaps, hardly fifty yards apart, maneuvers that would be mad on service.

There are such good elements in this field work that it is a pity to see it marred in any way by mistakes, which prevent it affording the instruction to the troops that it otherwise might. Again, it appears to us that there is an absence of explanation as to the designs of the operations. Each engineer officer gives himself heartily to the particular portion of the work allotted to him, but there is an absence of interest displayed generally in what is going on. The pleasure and instruction that might be afforded to officers who come to the ground as spectators is rather interfered with by the wholesale employment of policemen as sentries who act under very rigid orders. In conclusion, we would say a few words on the use of the electric light, which of

course could not be seen by day. Two of these lights were employed, each connected with a steam sapper, at 200 yards distance, which supplied the mechanical power necessary. The electric light itself is kept down behind the parapet. There is a reflector held up so as to be directed on any part of the surrounding country. The beam of the electric light is thrown up to this reflector and so on to any desired point. It is generally kept directed on a confined spot, the reflector being parabolic, but this can be modified by a lens if desired. The effect is very good indeed. Objects were admirably lit up at a mile range.—*The Engineer.*

THE GREAT PUBLIC AQUARIUM AT ASTON LOWER GROUNDS, BIRMINGHAM.

By William Alford Lloyd, Naturalist to the Establishment.

Twenty years ago, thirty years ago, even forty years ago, in the pleasant southern London suburb of Walworth, there existed what were known as the "Surrey Zoological Gardens," or afterward, when they were denuded of their animal contents, which once were their great and lawful attraction, before other and less healthy but more exciting sights and sounds were there seen, the "Surrey Gardens."

Here, in the year 1847, while the place was still "zoological"—some of the animals shown having been those formerly exhibited in the Tower of London, when it contained a collection of such creatures, they being deemed a fitting appurtenance to the royalty of Britain—I saw for the first and last time in my experience what I shall never forget or want again to see, the feeding by Cross of a constricting and non poisonous serpent on a living rabbit in a room in the gardens, mainly composed of glass, so that the admission of the summer sun should sufficiently heat the hothouse-like building to the right temperature for the reptiles confined in it. This sight of the feeding of the snakes, which attracted me, drew the attention of some one then much more important than I was, namely, Mr. D. W. Mitchell, the newly-elected and active secretary, or really, general manager, of the rival Zoological Gardens in Regent's Park, which, though owned by a learned body—the Zoological Society of London—was then in a very languid state of existence, almost closing, indeed, for lack of funds and public patronage. Mitchell was doing his best, and successfully, to infuse new life into the concern, and he took the hint afforded him at Walworth, to try to have an exhibition of reptiles in Regent's Park. The result was the reptile house on the south side of the gardens still to be seen there, much worm-eaten and overrun by ants as it is, and this was the earliest systematic attempt made by the society to show any lower animals than birds since its gardens first opened in the year 1828, so that a period of twenty-one years elapsed before any step was made to show anything like a connected series of creatures belonging to that interesting group which joins the lowest of the feathered bipeds with the highest of the fishes, and which includes neither.

Before going further, a word or two should be said of an individual who is now almost forgotten, and was the first one, during this century at any rate, to introduce to London and Londoners something like a fixed, as distinguished from a traveling, collection of living zoological specimens, and who, as I have named, was indeed the earliest to inaugurate the showing of reptiles, namely, the above-named Cross, the proprietor of the once famous Exeter 'Change in the Strand, opposite Wellington Street, where the poor mad elephant, "Chuny," had to be shot by a detachment of soldiers during a paroxysm of rage. Before me is an engraving by Barber, drawn by Shepherd, dated November 7, 1829, of this place, which was even then marked on the print "now pulled down." It shows a projecting corner house, on the front of which are three great inscriptions or signboards. The top one, over the third floor windows, has upon it "Exeter 'Change Royal Menagerie;" and below it, and above the second floor, is another, inscribed, "Edward Cross, Dealer in Foreign Birds and Beasts," while the third and lowest, which is placed over the first floor windows, is divided into thirteen compartments, the central or largest of which contains a picture of an elephant, while the six smaller compartments on each side inclose representations of lions, tigers, panthers, monkeys, a zebra, a rhinoceros, and some birds. A part of the place was occupied as billiard-rooms, while, as if to typify the aquaria which would be shown half a century later in connection with what were denominated "wild beasts," the engraving represents another part of the building as "Shell Fish Room," written on a large board extending over three windows, and owned by one Simpson, whose name also is shown "as large as life," and he is probably a forerunner of the famous one of the same name now living near the same spot.

Such were the means of exhibiting such matters in the metropolis of the world, half a hundred, or rather more, years ago.

Mitchell's venture with the animals lower down in the scale of existence than birds was so successful that he resolved at going down still further—namely, from and including fishes and to the very beginning, as it were of life, even down to zoophytes and sponges, thus comprising the mollusks, the crustaceous animals, the worms, the starfish and their allies, and the sea anemones, so that visitors should be able to see in clear sea and fresh water, and through translucent plates of thick glass, all manner of marine and fluviatile creatures, swimming, climbing, creeping, and almost or quite fixed, and of the most elegant forms and unusual coloring. This resolve was taken in 1850, and it was a direct consequence of the reading of a paper on the 4th of March in that year, by the late Mr. R. Warington, the chemist to Apothecaries' Hall, London, before the Chemical Society, on the manner in which he succeeded in maintaining some gold fish in unchanged water for a prolonged period.

The erection of the Regent's Park Aquarium, or as it was and is called, the "Fish House," was proceeded with slowly in 1851, and I first saw it from its outside, through its glass walls, on Thursday, November 18, 1852, at noon. It was not open, or even wholly complete, and it was indeed not opened to the public until 11 A.M. on Saturday, May 21, 1853, it being pictorially illustrated and described on one whole page of the *Illustrated News* of the following Saturday, May 28. It was and is a conservatory-like building, running north and south, measuring 54 ft. long, 30 ft. broad, and 12 ft high to the upper part of the vertical portion, and 20 ft. high to the apex of the doubly-sloping roof. Surmounting the breast-high brick walls, which originally formed the only opaque part of the building, are seven tanks on one side and six tanks on the other, each measuring about 72 in. long, 24 in. broad, and 24 in. high. Placed on the floor in groups, with walking spaces between them, are about eight other and smaller tanks, standing on wooden-inclosed cupboard-like frames, and one of these cupboards contains an arrangement something like an inverted iron balance, by means of which the two tanks placed over it can be alternately depressed and elevated in such a manner that the water may run in and out and so give a kind of semblance to a tidal action. This apparatus, however, has never been used. All these tanks, which still remain in the same position of more than a quarter of a century ago, have, save one, slate bases and ends, and glass sides. The two ends of this "Fish House" are arranged for small aquatic reptiles, as tortoises and alligators, and for the lesser aquatic birds.

Fresh water from the ordinary sources supplying the gardens generally, ran into one end of the larger series of tanks (those on the side walls), and, running right and left of the entrance door, emptied their uncontaminated streams into two sunken and not glazed tanks at the ends of the house, and from them it flowed to waste (so called), into the garden sewers. The smaller fresh water tanks standing on the floor, and unconnected with each other or with any other tank, had no current in them, and their water was but occasionally renewed, as it seemed necessary. The larger marine tanks had their water drawn from them, in part, every morning and every evening, by a gutta percha siphon, into slate cisterns placed below them, and from these cisterns it was pumped into a large slate cistern several feet higher up, and placed in the midst of a fresh-water cistern through which cold fresh water ran; the same cistern, in fact, which supplied, and supplies, the fresh water tanks. Thus the sea water received some degree of coolness in summer from the fresh water as it rose from the earth, it being raised by the steam engine generally supplying the gardens, and from this cistern it dribbled back into the show tanks through stoneware taps, being thus much aerated and refreshed by falling from a height twice daily. The other tanks, standing in the center of the "Fish House," and unconnected with any other tanks, were not thus cooled and aerated, and were changed or renewed occasionally as seemed needful.

All these arrangements, though here alluded to and written of in the past tense, are really those which still are in operation when this article is published. But it was soon found that the general construction of the building was wrong mainly in being too hot and light in summer, and too light even in winter. The consequence was a great mortality among the animals, and an excessive growth of the lower or parasitic green and purple vegetation which choked up much else; and even this excess of heat and light caused the sea water, and occasionally, but much more seldom, the fresh water, to become of a curious dark greenish-brown, opaque, and turbid hue, so that even large print could not be read through a space of three inches of it. Accordingly the glass of the building, sides, ends, and roof were painted opaque and white, and to further exclude the sun, and heat, and light, it was in hot weather screened with canvas. This, however, only somewhat diminished the evil without entirely remedying it, and it was then felt that a great error had been made in constructing the place, although, occasionally, some successes, by chance, or rather what seemed to be chance, were attained, as recorded, for example, in 17 lines at page 13 of the first edition of Mr. Gosse's "Aquarium," published in April, 1854, in which is mentioned the survival of several marine animals placed in the gardens "nearly a year" before, and that some of the sea water had not been changed for "seven months."

This passage of praise is, however, omitted in the second edition of the book, published in August, 1856, twenty-eight months later. For all that, and in spite of the frequent and perfectly needless renewals of sea water, which cost much money, and the equally unnecessary incessant changings of fresh water, which did not cost so much, however, because the apparatus and supply were already present before the Aquarium or Fish House was erected, this institution, and it only, which now seems so small and insignificant, gave an impetus toward what became from about 1855 to 1860 a real and impetuous aquarium mania all over Britain.

To increase the desire thus formed for having domestic fresh water and marine aquaria everywhere, and to supply it, books were written, now considered of not much value; tanks were constructed in a manner which is at present regarded of no great worth, as being utterly wrong in principle; and shops were opened to supply the rage thus suddenly awakened. I was one of these shopkeepers, and was, in fact, the earliest and latest in the commercial field. I experimented incessantly in the matter. Among other things I procured considerable quantities of both sea water and fresh water which the Zoological Society had used and done with, and cast aside as bad and useless, and from 200 to 500 gallons of which were in those days regarded as considerable amounts. It was of no consequence to me how evil-smelling such water was, how discolored from any cause, whether from excess of light or too little of it, from decay of animal or vegetable matter, from too high a temperature, or from all these causes united, of which the first-named, too much sunlight, was, for a long time, the worst to contend against, because it arose from the presence of enormous multitudes of locomotive spores of plants, of which it took over 5,000 placed in a straight line to measure one inch.

This foe, most frequently in sea water, but occasionally in fresh, for a long time baffled me, but I at length conquered it by simply reversing the conditions which brought it about—that is to say, I killed these plants, or rather hindered them from appearing visibly, by keeping from three-fourths to seven-eighths of the water in absolute darkness and only the remaining fraction in daylight, and then I maintained a circulation between the two. For the rest, I regarded water as an absolutely indestructible material, with which I had to work merely as a chemical combination of oxygen and hydrogen, or as an oxide of a probably very volatile, and, as yet, undiscovered, metal called "hydrogen," capable of being mixed up and combined with many other things—capable thus of being formed into steam, hail, rain, ice, snow, dew, hoarfrost, and other modifications, but of always being capable of being freed from these, and freed from all fluids or other substances, both in a state of chemical combination and of mechanical mixture, and which we and other animals drink and ordinarily use for very many purposes, and of being brought back at pleasure to its primary condition of nearly pure water—for absolutely pure water, in contact with our atmosphere, is almost impossible of acquisition, even when sought to be produced or maintained as such by a skillful chemist.

So I regarded the presence of all bodies in it, in suspension or in solution, as being foreign to it, and always capable of removal or of addition in any combination whatever, up to saturation point, when no more can be added. Therefore, I readily removed all decay in any stage by a process of oxygenation or of union with free oxygen (as distinguished from oxygen in combination), which oxygenation is really a process of slow burning at a low temperature without the presence of actual fire, just the same as a rapid burning at a high temperature and with actual flame, is a process of quick oxygenation. This I applied to both sea and fresh water, leaving both of them bright and clear, and perfectly fit for aquarium purposes for any length of time, with no further need of change or renewal except to refurnish loss by evaporation; and even that loss is not really a loss, but merely a change of place of fluid. And this I did, I repeat, to water which had been used in aquaria, and which was wrongly regarded as spoilt and valueless and only fit to be thrown away in waste. But those who proposed to thus throw away and waste it, did not think or know that in so casting it away out of sight as a noxious thing, it was not in reality wasted in any degree, but only returned with absolutely no diminution to the grand system of aqueous circulation of the whole world or earth, or of the entire universe, and which circulation is so constantly maintained by that great source of all motion and heat and life, the sun. Indeed, there never has been, nor can be, any loss whatever of water, heat, or power.

Furthermore, I regarded all water on the face of the earth as having been at first fresh water, or water ideally containing nothing in solution; and, again, that sea water was gradually formed, or evolved, by this circulating system; that is to say, the sun, shining on water everywhere, or wherever water is under its influence, so as to cause it to be of a higher temperature than freezing, then such water evaporates and rises upward into the air, where it is cooled and falls again on the earth, forms rills, brooks, rivers of various dimensions, lakes, and so forth; and these, in their progress toward the sea, which is their lowest point, carry down with them whatever is soluble in the land, and especially in the gradually disintegrating rocks of the land. These matters in solution, consisting in their far greater amount, as found in the ocean, are composed of chloride of sodium, or common table salt, of which the river Thames, to give but one example, carries down to the sea nearly one ton weight every minute.

The varying saltness of all seas—from those, as the Dead Sea, containing so much salt that only a few creatures can live in them at all—to those, as the Baltic, Caspian, and Aral seas, containing so little salt that some fresh-water animals live in them as well as marine ones—can all be accounted for by their surrounding circumstances. From this, and from an analysis of the whole constituents of sea water, I found I could not only convert sea water into fresh water, but also easily convert fresh water into sea water, and save very much money by avoiding its carriage from the sea to a place so far from the ocean as London, where I worked, and where, in the cool cellar and back kitchen of a house in Clerkenwell, the lower part of which I rented for the purpose, I was very successful in these my humble, though I hope intelligent, representations, but not imitations, of nature. It was in this place, which I maintained as desirable for British occupants of seas and rivers, at a temperature of 60 deg. Fah., that I ascertained how wrongly I and all others had been acting in depending for our sources of oxygen primarily upon plant life, instead of upon mechanical aeration, in the first and largest degree, by exposing water to air, either by an increase of comparative surfaces of water, or, more conveniently, by inducing currents of air and of water, or much less desirably, of air only, which enormously increased such surface contact in a small space. Certainly, I found that no amount of mechanical aeration would be of much service in the absence of plants growing in the water to absorb and get rid of the carbon which the animals exhaled, and which, remaining, is so injurious to them; but, on the other hand, I found it most inconvenient, and almost impracticable, on anything like a large scale, where difficulties and complications are increased by dimensions, to depend on plant life in the precise manner recommended by the early experimenters, as indeed Nature herself never does, and she should always be our guide.

So all my working, at this period and at subsequent times, pointed to the fact that the actual bulk, by weight, of effective plant life in aquaria need not be great for its chemical influences, so long as it is healthy and growing and covers large surfaces. Then, too, I perceived that Nature is so eagerly solicitous, as it were, for the presence of this most necessary vegetation, that it comes in a quasi-spontaneous manner (which, however, is not really spontaneous, as something can never come from nothing) whenever water and daylight coexist. This is a curious fact; and, in addition, the character of the vegetation depends on the character of the water.

Thus, marine algæ, or lowly-organized vegetation, will appear in perfectly pure and plantless sea water in light, whether such sea water be concocted in the ocean by nature, or be prepared by man in inland places, and fresh-water algæ will similarly come in fresh water. More than that, algæ of corresponding characters, of gradations between fresh and salt species, will appear in like manner in waters composed of much varying but ascertained mixtures of fresh and sea water, from a very slight degree of salinity up to the greatest strength which sea water is capable of attaining—that of the Dead Sea.

Still more remarkable than even this, sea water has been carefully prepared with distilled water and the necessary salts, and then boiled to kill all germs. Yet, on becoming cold and on being exposed to the atmosphere, in a part of England more than 100 miles from any sea, true marine algæ have formed in such water on being exposed to daylight for some weeks, showing how the wind, ever blowing from all quarters, blow algæ seeds from the sea coasts. This also shows strikingly, and on a small scale, but certainly in an uncontradictory manner, the absolute and very gradual interosculation of the entire water system of the universe, embracing every possible collection and condition of water, from the purest to the most impure, and from that containing the least amount of matter in solution to that which holds most of saline ingredients. There is not, and there cannot be, any separation of them, or any real isolation of one from the other, or any actual independence between them in the whole of nature. All are not only governed by the same laws, but all are more or less closely connected.

This is most admirably shown in a Parliamentary Blue Book, on "The Domestic Water Supply of Great Britain," 525 pp. folio, 1874, with many large folding colored maps, diagrams, plans, etc. In this wonderful and comprehensive volume, every kind of water found in the British Isles is dwelt upon, and the causes of its peculiarities described, from rain water containing no more than 4½ grains of total foreign matters in each gallon of 70,000 grains, up to the most dense sea water and turbid fresh water we have, including some waters very dangerously charged with poisonous excremental pollutions in situations where they can be and are used for various drinking and other purposes. One of the illustrations in this book is a facsimile of a letter written, not with ink, but with the water of the river Calder, in Yorkshire, and it appears quite distinct and of a pale gray-

ish-purple tint on the paper. And it would be easy to extend the inquiry to other countries, and to show, among other things, why the Mediterranean and Red Sea waters are denser than any British sea waters, and why the Dead Sea water in Palestine is salter than any.

Armed with such knowledge as this, not then to be found collected in books, I, in 1860, went to do aquarium work in Paris, in the Acclimatization Gardens, where Mitchell, shortly before his death, just previously, had planned an aquarium, and had seen its shell, or its containing building, set up. In doing this, he had carefully avoided one of his former errors in Regent's Park, London, in making it a structure freely and readily permeated by daylight. In Paris, no light whatever could enter the spectators' part of the building, except through the water in the tanks, each measuring about 6 ft. long and 4 ft. broad, and each containing about 200 gallons of water. These were, and are, fourteen in number, ten being sea water, and four fresh water, all ranged end to end, in one straight line, facing the north, with light admitted in one overhead direction only, and not too much of that.

So far so good. But Mitchell had not only not planned the tanks, which I arranged to be made of slate, with only one side of glass for the inspection of the interiors, all the light to be admitted from the top, through the surface of the water; yet Mitchell had not devised any mode of aerating the water, by circulation or otherwise, and he, in fact, had told me, as many persons have done since, that he had no faith in any use of unchanged water. But I have now, and had then, no idea of what contrivance he intended to adopt to maintain the water in a clear and respirable state. I believe he had a good notion, but was confused by a multiplicity of counsel. For example, a Dr. Ball had arranged a small aquarium in the Zoological Gardens in Dublin, in which water aeration was depended upon by visitors being invited by a printed bill to each of them to work a pair of bellows for this purpose; and at Scarborough, in the museum there, visitors were similarly invited to take turns at a kind of water wheel.

However, I resorted to my plan, which has never been equaled, of having a great underground reservoir in a cool and dark place, and in Paris I lifted the sea water from this reservoir by means of air compressed by fresh water from the city water works. This acted admirably, and it is still in action, with the same water unchanged for nineteen years. I could not persuade the company I was engaged by to let me incur the additional expense of circulating the same fresh water in the same manner, and therefore it (the latter) has ever been of fluctuating quality as to clearness and general suitability for the animals, as would not have been the case if we had not had to depend on such fluctuating supplies as we could have from outside, but have been sure of our own quality got from our own unvarying and unchanged sources. Neither had my masters any faith in my compounding sea water from salts, so they went to the needless expense of getting it from the sea. But I made a very serious error in Paris, namely, I arranged an outlet to each tank, instead of making the stream run continuously from one to another. The consequence of this blundering was that the machinery had to raise about ten times (nine times at any rate) as much water in a given time as it should have done.

In 1863, I went to Hamburg, and made a somewhat similar aquarium to the Paris one as to general principle, but larger, and with more variation in the dimensions of the tanks, there being greater ones for the larger animals and smaller ones for those of lesser size; and, instead of, as there, using that city works' water pressure to compress air to drive the water circulating machinery, I employed this pressure in a direct manner, in a double-action horizontal cylinder, with a cam reversing gear, and without the intervention of air. This arrangement, as in Paris, worked very well day and night without constant manual attendance; but at Hamburg, as the city so quickly enlarged its boundaries, the water pressure became by degrees too weak for our aquarium work, and we had to substitute steam power. At Hamburg, too, we, for the first time, and with great advantage, circulated the same unchanged fresh water, as well as the same sea water. These have both now been unchanged since 1864. We used sea water from Heligoland because we had it given to us, and it cost us nothing, otherwise I should have proposed concocted sea water, as being at least equal in goodness to the other. It could not, at least, be worse or better than water got direct from the sea.

At Hamburg I repeated my Paris error of raising about ten times as much water as I needed to have done, but was afterward fortunately able to correct the mistake into four times as much only. But the Hamburg aquarium was a very great success, and it stimulated in the same direction many other places, as Hanover, Berlin, Vienna, Breslau, Dresden, Brussels, Frankfort, Boulogne, and elsewhere, and in each of these large public aquaria were set up from 1865 to 1870. In the last named year the Crystal Palace, hearing and seeing how successful I was at Hamburg, invited me to make and manage a similar one at Sydenham, and I accepted, and in August, 1872, it was opened to the public. I endeavored to have its construction made as well as possible, but like many other things in and around that great palace of glass, it was unduly hurried in building, and the foundations were not good. Consequently the aquarium has always leaked more or less, and it is not certain that this defect can ever now be remedied. In general principle it is like those I did in Paris and in Hamburg, and steam is the motive power by which the sea water is circulated. No fresh-water tanks have been added to the system.

The Crystal Palace Aquarium has been, and is, most successful, the same sea water having been used from the beginning, and in this has been oxygenated and chemically got rid of, without any mechanical removing, an enormous amount (many tons in weight) of the excrementitious results of food eaten by a very great number and variety of animals, representing more completely our British marine fauna than any other English aquarium ever has done, because considerations of light, temperature, and perfect aeration have been attended to

This is science, and science only means uncommon knowledge applied to common things. In spite of these great numbers of species and of individuals, however, the water has ever been singularly clear, and the amount of manual cleansing needed to be performed inside the tanks has been, and is, marvelously small. Much of this I believe I am right in attributing to the peculiar formation of the sand and shingle placed in beds of six inches thick at the base of each tank, and which possess, in a marked degree, the property of mechanically entangling enormous quantities of air in bubbles, so that such beds of gravel seem to be ever charged with air, even to saturation, and the presence of this air seems certainly to exercise a very marked and immediate influence on the oxygenation of the organic matters which fall down upon it, so that it is very quickly dissipated. At the Palace Aquarium, with a perversity which now seems to me inexplicable, I again blundered in the matter of needlessly raising too much water, but this time only to the extent of fifty per cent. instead of ninety, as at Paris, and sixty-five or so at Hamburg.

It is needless to pursue this history much further, save to say that anywhere, in and out of Britain, wherever success in aquaria has been attained, it has been achieved by endeavoring to follow nature in the manner I have here indicated; and whenever failure has happened, as it has done direfully in every one of the Paris Exhibition Aquaria, from the earliest one in 1855 to the latest one there, last year (1878), it has been because of a departure from the indications of nature, which are to be so clearly seen and read by every willing and not self-satisfied student. One of the things taught, however, with the greatest difficulty to aquarium owners, both public and private, is the necessity of waiting patiently till the water is in right condition before animals are introduced. Water alone has no power whatever to sustain life, and it is only a necessary medium or vehicle for that which does maintain existence.

After so many public aquaria have been made in various parts of Britain and the continents of Europe and America (one is now contemplated in Australia to be arranged by me), I am happy in being associated, from the beginning, with one at the Lower Aston Grounds, near Birmingham, in which all the gradually gathered experiences of the last quarter of a century are gathered together with singular felicity in one great and economical whole, and which has been called into being, mainly by the enterprise of Mr. G. S. Quilter. In this work I have had, as naturalist and general arranger, the pleasure of being associated with a set of gentlemen of much tractableness, consisting of Mr. Thomas Naden, as architect; Mr. J. Garlick, as builder; Messrs. Leete, Edwards, and Norman, as engineers-in-general; Messrs. Maccabe and Sutton, as electrical engineers; and Messrs. Southall Brothers and Barclay, as chemists in the manufacture of the sea water, on which last-named item a sum of not less than about £1,200 is saved on 300,000 gallons, compared to what it would be if obtained from the ocean, while this water is being so skillfully compounded by Messrs. Southall's analyst, Mr. Jones, that no marine animal, and no chemist, can tell it, in any way, from that which has been brought from the coast, while no renewal of it will ever be needed.

The building is made of red, black, and white bricks, baked purposely for it, and these are interspersed with white stone columns and other decorations, having upon them, in their capitals and elsewhere, several hundreds of carvings, all of different design, and executed by the Brothers Naylor. The principal room, or saloon, measures 320 ft. long and 60 ft. wide, which in the center expands to 85 ft. wide, there being a lateral semicircular apsidal projection containing a series of small tanks on its outside or periphery, and a pond for seals and other similar creatures in its inside area. All the smaller tanks are, indeed, on the eastern side of this noble saloon, and they are thirty in number, of which six are for fish hatching on an improved plan in several respects, in unchanged, and therefore always pure, water. All the larger nineteen tanks, measuring each from 15 feet to 20 ft. long, 7½ ft. broad, and 5 ft. high, are in one long row on the western side, the longer axis of the room thus running north and south, as that allows of more equable daylight than any other aspect, while the light will be admitted to each tank in a very effective, and, so to speak, scenic manner, and the admirable rockwork, now being erected by the practiced hand of Mr. Pulham, much aids this effect.

Asphalt, by Stodart & Co., lines all the tanks and reservoirs, thus securing absence from leaks as much as possible, while a further security has been sought by dividing the huge underground reservoirs into seven compartments, each capable of being isolated in succession, or in any order, from its fellows, by valves of vulcanite, of which material all the pumps, pipes, jets, and other portions of the circulating apparatus in contact with water, both salt and fresh, are composed. This isolation enables any compartment to be emptied and examined without interfering with or wasting the rest of the water, which is a valuable contrivance.

The reservoirs are all below ground, and are of an aggregate capacity of about five times that of the exhibition and reserve or hospital tanks, of which latter there are ten, in a part of the building not open to the public. These are good arrangements for containing animals in an unhealthy or otherwise unpresentable state, or for storing living food, etc. The fronts of the tanks are of polished granite, and below the bosses, and on the pilasters dividing tank from tank, are Minton's tiles of much varied pattern, one pattern to each three tanks in the entire series.

The floor is also beautifully tiled by Minton. Over each of the larger tanks is a circular painting, 4 ft. in diameter, in stained glass, by Bourne, there being nineteen such, and two smaller ones, each giving an appropriate aquarium illustration of Shakespeare, with a suitable motto of his. Indeed, the lavishness, perfect good taste, and subdued character of all the decorations, is a conspicuous feature in this finest and most complete aquarium yet built or conceived.

There are two steam-engine boilers, giving motion to no less than six steam engines, some for circulating water, some for electricity and for other purposes, all the machinery being placed together at the south end of the building, the whole range of which is surmounted by a splendid picture gallery 500 ft. long; and it is joined at right angles at its northeastern corner by a magnificent concert hall and theater, 400 ft. long and 100 ft. high.

Reverting, finally, to the biological part of this splendid work, I have to say that all possible means have been taken to secure scientific success, so that the place may be considered a vast machine for the advancement of natural history science, in which the careful duplicature of the apparatus leaves no pause or stoppage of motion of the water anywhere.

It is in no ungrateful spirit of looking back on the "day of small things" that I now write to say that, comparing this Aston Aquarium to the earliest public one by Mitchell in Regent's Park, is much like comparing a great battery, composed of huge Armstrong guns, to that famous but feeble row of cannons hollowed out of trunks of trees, as described in Milton's "Paradise Lost." And even comparing it to the efforts made twenty years ago in Hamburg, Paris, and the Crystal Palace, it is like comparing modern artillery—accurate, penetrating, and far-hitting—to the instruments with which Waterloo was fought.

May this aquarium do much for our scientific knowledge as well as for our amusement, and much also against cruelty to animals. At present I write with regret that in no language is there any good account of even one department of zoology—namely, our British marine fishes—in a state of life and health; while, if I wish to read about English fresh water fishes in a reliable manner, I must go to, not English books, but untranslated ones in the German language, by Von Siebold, and Haeckel, and Kner. And it is the same with all aquarium animals of rivers and seas, ranging from fishes downward to sponges, in all books, in all languages.

INTERNATIONAL AGRICULTURAL SHOW, LONDON.

THE greatest agricultural show that the world has ever seen was opened at Kilburn, London, July 1 An area of 103 acres was covered with rows of shedding for implements, cattle, and various kinds of agricultural produce, with rings for the judging and parading of the live stock, and with refreshment-booths, the members' club, the grand stand, offices, dormitories for foreign herdsmen, and other buildings. We give some illustrations on next page.

The total entries of live and dead stock reach the extraordinary number of 25,777, consisting of 22,903 entries of implements and other exhibits—which are not all "dead stock," as some of them are vegetables, seeds, and plants—and 2,874 entries of live stock. These numbers, both in regard to the grand total and the separate divisions respectively, are largely in excess of those of any previous show. At Liverpool, two years ago, the entries of implements, etc., mounted up to 15,796, which was then considered a very large number; but at Kilburn we have 7,107 in excess of the Liverpool entries. Then, as to the live stock, there were at Bedford, in 1874—the largest previous show of live stock, we believe—1,527 entries; but at Kilburn we have 1,347 in addition.

But what is more important than the increase of the show in size is the increase of the attractions which it offers. Systems of farming cannot be seen in a showyard, but almost everything agricultural that can be exhibited in such a place may be seen at Kilburn. The finest horses, cattle, sheep, and pigs that the world has produced are there. We have a show of breeding-cattle and a dairy-show, goats being included. In the dairy department there is not only a show of the finished products of the dairy, British and foreign, but also an exhibition of butter making on the English, French, Danish, and Swedish systems, and of cheesemaking on the plans in vogue in this country, Denmark, Holstein, and Limburg. The exhibition of bees, hives, and honey, with illustrations of the most successful methods of bee-manipulation, possesses great attractions to many visitors.

Side by side with the latest inventions and most finished adaptations in agricultural machinery, implements, and tools, there are some of primitive form, many of which have seen good service in the past and are not yet entirely superseded, and others chiefly interesting as curiosities of unperfected ingenuity, enough, so some people say, to upset half the modern patents. When we come to the vegetable department of the show, we find in that also new attractions. The great British seed firms have at once enriched themselves and made the world of agriculturists and consumers their debtors by the results of their enterprise, directed by special knowledge and opportunities. In roots, cereals, forage plants, and garden vegetables they show the developments of a system of artificial selection culminating in the prearranged "survival of the fittest." A comparison of the field and garden products of to-day with those of twenty, or even ten, years ago shows a wonderful progress. But the interesting display of our seedsmen is no new feature in agricultural shows. The novelties at Kilburn are the collections of the agricultural produce of India and several European countries, together with a loan collection from South Kensington Museum, illustrating the composition of foods.

We here proceed to notice the particular objects shown in our illustrations, following the order of the engravings as arranged on the page.

No. 1 is a Crimean three-furrow plow, as formerly used in that country, but now superseded by the modern three-furrow iron plow. No. 2 is the Java plow, as made in that island, and used in the present day. No. 3 is the Egyptian plow, still made and used in Egypt, which is almost identical with those shown on the ancient Egyptian monuments, and may be considered the earliest form of plow. No. 4 is the Suffolk "gallows" plow as made 70 years ago, and still in use in that county. These four plows are lent by Messrs. Ransomes, Sims, and Head, of Ipswich.

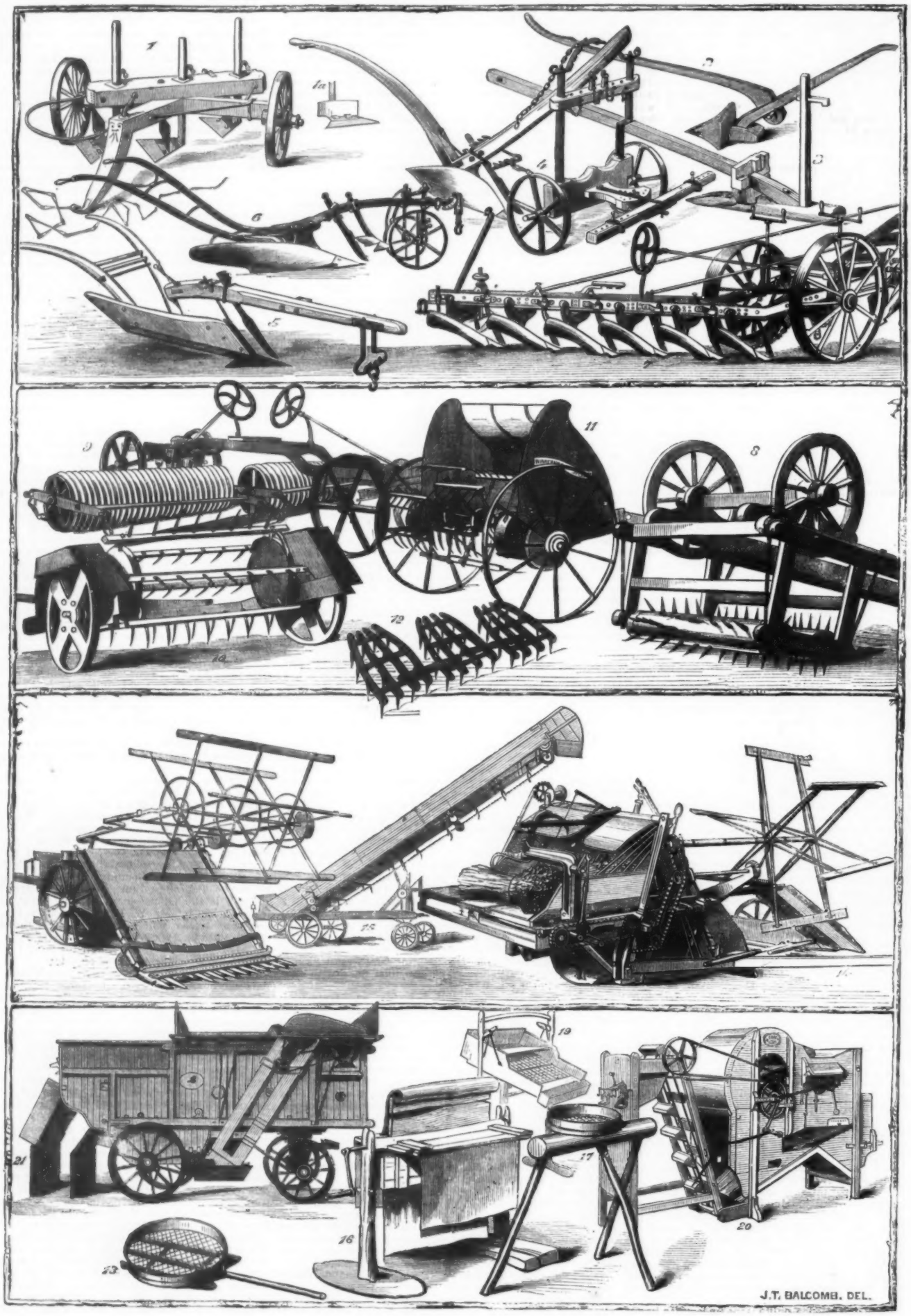
No 5 is the Gloucester Vale long plow, nearly a century old, lent by Mr W. Lawrence, Pirton Court, Gloucester. The reader will contrast this and the other wooden plows, antique types, with the graceful light appearance of No. 6, a plow constructed on the most improved modern principles, entirely of iron and steel.

We next direct attention to a steam balance plow of the most recent principle (No. 7). Little more than half this great implement is given in the illustration. It is made sometimes with as many as eight shares on each half. The frame-plan of this implement, looking at it from above, is that of two parallel lines resting on the wheels; these parallel lines are bent inward, at obtuse angles, beyond the circumference of the wheels, and thence continue till they meet, so forming the rigid iron frame, which is always at an angle to the line of direction when the plow is at work. The alteration of the width of the furrows is effected by means of wedges, which fix the shares at different angles to the frame.

As many of our readers may not be familiar with the method of steam cultivation, we here add a few words of explanation. One mode is by the double engine system; that is, using two self-moving steam-engines with winding drums under the boilers. These are placed parallel to each other at opposite sides of the field to be operated upon. The implement is pulled towards the engine across the field, the other engine, not in work, paying out the rope while moving forward into position for the return journey. This alternate pulling by each engine is continued till the task is complete. The other mode of working is by drawing the rope to and fro between the engine, placed as before at one side of the field, and a ponderous anchor, which has automatic self-moving action, at the opposite side. The framework of this anchor rests on thin disk wheels, which cut into the ground to enable it to resist the side strain of the engine and implement. The automatic arrangement keeps it moving along so as to be opposite its work.

In the collection at Kilburn all the steam cultivating machines are placed by themselves apart from the other agricultural implements. The visitor is thus enabled to judge of the different appliances, as connected with each other, in their proper order. Our space being limited, we have placed this steam plow and the steam clodcrusher (No. 9) with the ordinary implements of their class to assist the comparison.

No. 8 is a very old self-cleaning clodcrusher, lent by Mr. Thomas Drewitt, of Pickards Farm, Guildford. The frame and shaft of this are more modern. The clods in a field having been crushed, it is turned over on to the wheels, the



1. Crimean Three-Furrow Plow. 1 *a*. Side view of Share.
2. Java Plow.
3. Egyptian Plow.
4. Suffolk Gallows Plow.
5. Gloucester Vale Long Plow.
6. W. Ball & Son's Criterion Plow.
7. Fowler's Steam Balance Plow.
8. Self-Cleaning Clod Crusher.
9. Fowler's Steam Roller, or Clod Crusher.
10. Hay Kicker.
11. Jeffery & Blackstone's Haymaker.
12. Harrow.
13. Bell's Reaping Machine.
14. McCormick's Reaping and Self-Binding Machine.
15. Clayton & Shuttleworth's Corn-Stacker.
16. Winnowing Fan.
17. Ridder and Horse.
18. Ridder.
19. Improved Ridder.
20. H. Cooch's Corn-Dressing Machine.
21. R. Hornsby & Son's Finishing Steam-Thrashing Machine.

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horses draw it to the next field, and are then taken out, and the machine is turned back again, so that the spiked rollers are underneath, as seen in the engraving. Compare this with the steam clodcrusher (No. 9), which consists of a number of strong cast-iron wheels, with wedged edges; each wheel has an independent revolution. The total width of this steam roller is fifteen feet.

No. 10 is an old double-action haykicker, said to be of the first make, or about fifty years old. It is lent by J. D. Ostler, Esq., of Walrond Park, Taunton. It has no screen between it and the horse, to protect it from the showers of hay kicked up; the attendant walks by its side. Compare this rude contrivance with the beautifully-finished haymaker, No. 11. This has a seat provided for the driver, which is not seen in the engraving, being hid from view by the solid screen or shelter. In such a vehicle a well-dressed lady would be enabled to ride about all day in the fresh air without her apparel being any the worse for it.

No. 12 is an old harrow, roughly made from branches of trees, the tines being of iron. It is lent by H. Downes, Esq., of Basingstoke. This may be compared by visitors with the modern, beautifully-finished, and far more effective harrows to be seen in the Exhibition.

We now come to a machine of a highly interesting character—the Rev. Patrick Bell's reaping-machine (No. 13), the first efficient one of its kind, made about 1826. By comparing it with the modern reaping-machine at Kilburn one remarkable difference will be noticed. In the latter the horses pull the machine with its knife behind them, whereas in the first machine they pulled the machine in a direct line to the front of them. A peculiarity in the knife of Bell's and also in that of McCormick's, another reaping-machine which came after Bell's in point of time, is that the knife is finely notched like a saw.

In No. 14 we have a machine which binds the sheaves before depositing them on the ground. Our illustration almost tells its own tale. The principle of the binding consists chiefly in using a curved swan-neck arm at the side of the binding-table. This arm works forward towards the corn to be bound, when the binding wire from a small pulley embraces it, and, by the arrangement of a shuttle traveling underneath the platform, the circle of the binding-wire round the sheaf is complete.

The corn has next to be stacked; and in No. 15 we have a labor-saving apparatus called the "stacker." This was introduced some years ago by Messrs. Clayton & Shuttleworth, and has been found to supply a want long felt at harvest when labor is scarce. The days of the pitchfork, sickle, and scythe are going by, but labor-saving contrivances take their place. The stacker proper differs somewhat from a straw elevator, as corn requires a different treatment from loose straw; but this stacker is applicable to both purposes.

No. 16 is an old winnowing fan of probably three centuries ago. It is lent by Mr. Etches, and is most likely the oldest example extant. As the winnowing machines are arranged in this collection, the progressive improvement of the fan is noticeable. We notice the first development of the fly-wheel (four cross pieces at the end of spokes) to which the handle is attached; then, in another machine, the fly-wheel, complete; afterwards the canvas to be twirled round is attached to the circumference of four wheels, having spokes from the center axis. No. 17 is a ridder, or coarse sieve; the spaces in the bottom of this sieve are about half an inch wide. It is resting on the horse or trestle. The manner of using this winnowing tackle was as follows: By means of the handle, four canvas flaps were made to revolve rapidly, so that an enormous draught was created; and, by another operation, the ridder with the corn in it was slid backwards and forwards on the top of the "horse," used as a rest to keep it at about one height. The heavier corn fell through direct on to the ground; the lighter corn was blown by the wind a little further off, thus roughly sorting the finer grain from the common. The chaff was sent right away from the neighborhood of the grain.

No. 18 is a ridder of larger size and coarser bottom, and, as will be seen, was held by its long handle without a horse. The last two are lent by H. Downes, Esq.

No. 19 (in the background) is a ridder of improved design of date about 1812. It forms the transition state between the last-described and our next illustration. This ridder was used with a fan. It was suspended from the short projections near the top of the frame. The corn having been put into the upper compartment, sideways, motion was given to the ridder by the hand. The corn fell through the bottom of this compartment, running in its passage down over the face of the first wire-gauge; but foreign small seeds, with their chaff, fell through here and away by a spout underneath. The lower sieve was coarser; here the corn fell through, and would be acted on by the fan, as described. The open trough at the foot of the ridder was for the purpose of catching thistle-heads, stones, and other large foreign matters too big to fall through the wirework with the corn.

No. 20 is a corn-dressing machine of the most improved modern construction, placed as a contrast to the ruder implements just mentioned. The old corn-dressing machine similar to this, also exhibited at Kilburn by the owner of No. 20, was patented in the year 1800 by Mr. John Cooch, of Harlestone, near Northampton, and is the oldest complete corn-dressing machine known to be in existence. As the one in our illustration has never taken any other than first prizes, it is fitly taken as the termination of the scale of improvements commencing with the old winnowing-fan. In this corn-dressing machine the winnowed corn falls out at the end, and is carried up from the flows by means of tin troughs to the top of the elevator, as this part of the apparatus is called. It there falls into the sack's mouth out of the spout.

No. 21 (seen in the background) is an improvement on the flail. In the usual order, this would come before winnowing machines; but, as the subject of our illustration is a finishing thrashing machine—that is, one which beats out the corn, winnows, sifts, and delivers it into bags, it is more properly placed last. Thrashing machines were invented in Scotland about 1758 by a farmer in the parish of Dunblane, Perthshire; but was constructed on the present improved principle by Andrew Mickle, a millwright, of Haddington, about 1776. The machine may be roughly described as consisting of a cylinder, or drum, furnished with beaters, which strike the heads of corn when protruded through fluted rollers. The ears having been thus pounded, the grain falls through some wirework into a winnowing machine. This feature of Mickle's mill is, with some minor alterations, adopted in all thrashing machines constructed in the present day. The motive power used for that shown in our illustration is steam.—*Illustrated London News.*

THE IOWA STATE AGRICULTURAL COLLEGE, AT AMES, IOWA.

THE following article is from Prof. Knapp, in the *Western Stock Journal and Farmer:*

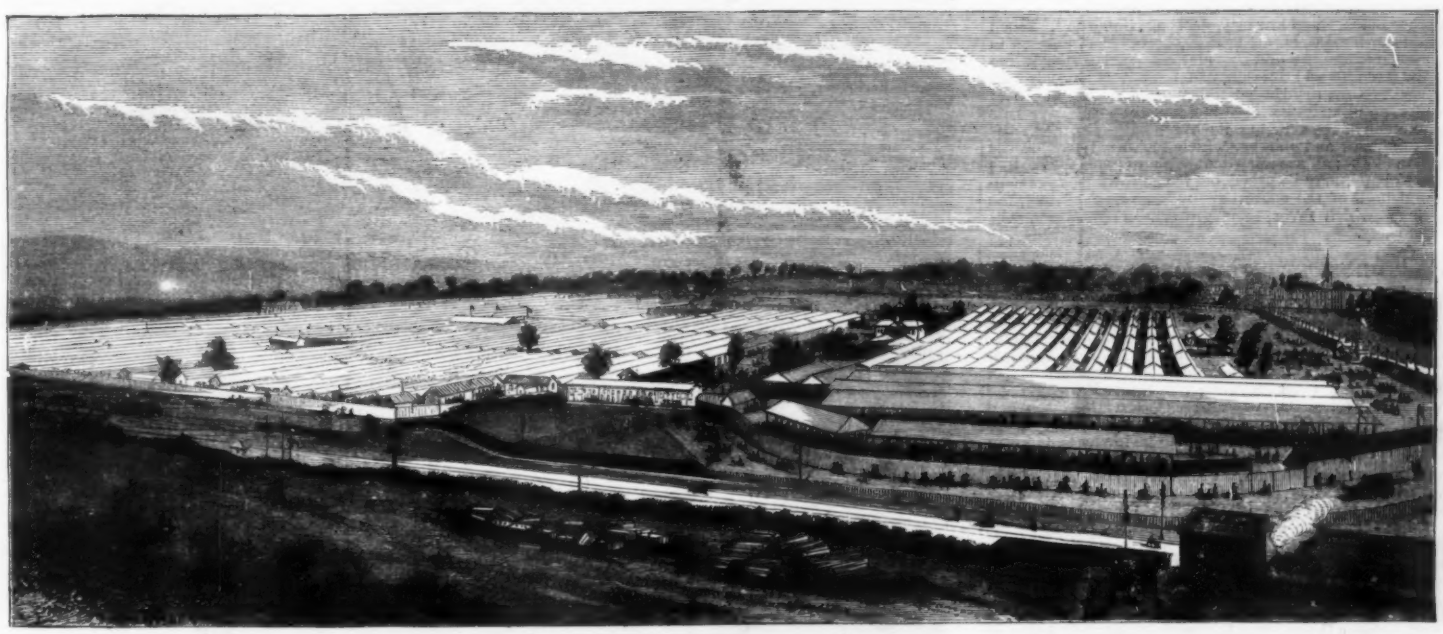
An old-fashioned stage coach backed up to the hotel steps at Ames and invited us to ride to the college. In the coach were professors Macomber and Beal and several pupils, on their way to the school; nearer the grounds we were joined by President Welch; inside the gate a broad graveled road leads up to the main edifice, furnishing a fine view of the grounds and the buildings; at the steps the driver says, Whoa! we deposit our quarter and enter the building; president's room on the left; parlor on the right. Like all good pupils asking admission to the college, we pay our respects to the president's room and ask permission to visit the places of interest. He takes us in charge—it is well to have the president's eye on green boys, just entering college—and leads the way first to the library. On the way we call at the treasurer's office and greet Gen. J. L. Geddes, the careful financial manager. After paying our tuition and board in advance we bow ourselves out and visit the place of books. The library room is large and arranged with the usual alcoves for the books; but the books are the main attraction—a grand array of practical and scientific works, with a good sprinkling of English classics. It is one of the best libraries for science and agriculture in the United States.

From the library we ascended to the cabinet. The collection is not large, nor did we observe any rare specimens, but everything was neatly arranged and well classified. From the main building we are invited to the building of science and mechanics. In the basement is a good machine-shop, where the young men can make anything from a swivel link to a steam engine; and closely connected with it is the wood-shop, with saws, planer, bits, and engine. Prof. Thomson was on duty, and has shown himself a man of device as well as practice. He has thrown his ideas to the wind in the form of an ingenious wind-engine, which will be shown at the Iowa State Fair. Now we visit Prof. Pope at the laboratory; basins, bowls, retorts, receivers, oils, metals, bases, alkalies, acids, agents, and reagents upon every hand; the largest and best arranged laboratory in Iowa, with a professor who fills every square inch with the enthusiasm of scientific investigation. We ascend a story and Professor Macomber welcomes us to the department of physics, which consists of an office, a fine lecture room, and a room to store the apparatus necessary to illustrate the lectures. Everything seemed prosperous in the methods of instruction, but the instruments did not use us fairly. The mirrors made us look too large or too small; the wedges and the pulleys were disposed to take advantage of us; the inclined plane to present obstacles; and the scales to throw us off our balance. We concluded to retreat before our optics and acoustics were seriously injured.

Prof. Budd accompanied us to look at the young orchard, some twelve hundred trees, tops worked with Russian varieties. The grafts were worked on Gros Pomier stock, and exhibited the thick, firm leaf and vigorous growth of the Russian apple. The professor also showed us a field where he was experimenting with one hundred varieties of potatoes. The State of Iowa cannot fail to derive great advantage from such experiments. The call of dinner brought us to the dining-hall, where president and pupils join in a rattle of dishes and clatter of knives, where the dynamics of soup cause a constant overflow of the conversational powers, while the abundant solids are rapidly inducted into the gastronomic retort. Here is revealed the great secret of the splendid physique of the two hundred pupils in attendance at the college. After dinner, Mrs. Welch shows us the model kitchen, where the young ladies are taught the mysteries of house-keeping, a department too often neglected in the course of instruction deemed necessary for a complete education. This trial department in scholastic life has been wisely placed in the hands of one who will make it a success, if success be possible.

On our way to the veterinary department to see Prof. Stalker, we called upon Prof. Bessey, who was occupied with a class of pupils discussing rust upon grain. Each pupil had a microscope carefully examining rust in its various stages of formation. Soon we were squinting through orifices and adjusting lenses, as delighted as a new pupil. "We spend a whole year in the cryptogams," said an interested pupil; not too much time, we thought, to understand the marvelous history of the flowerless kingdom. We left the professor in the midst of his rust, and changing our course crossed the campus to visit the stock and creamery. The stock was mostly out to pasture; saw a few fine calves and the bulls—not enough to give any just opinion of the stock department. Everything on the farm seemed thrifty and well managed. Crossing the campus again, we visited the veterinary department, and, passing through all the rooms, failed to find a student or the professor. We went out to the barn and found the class practicing. On Friday of each week, any one can bring an animal for examination and operation, without charge. Just as we arrived they were about to extract the "wolf" teeth from a colt. They threw the colt and drew the teeth in a short time. This department of animal clinics is certainly a very important matter and one that will give to Professor Stalker a deservedly wide reputation. We should not do justice did we fail to mention the new horticultural building, a very complete and substantial structure, erected at the extremely low cost of $2,500, and a standing refutation to those who claim that public buildings cannot be erected economically.

The Iowa Agricultural College is doing an excellent work, and reflects the highest honor upon the organizing ability of its scholarly President and its efficient Board of Trustees. The processes of education are complicated and the results are not always evident until the seal of time has been placed on the solution of its problems. When passing years have terminated the friction incident to an energetic life and the crossing of purposes resulting from large formative and progressive power, we shall more readily recognize and appreciate the wisdom which has founded and directed methods of education in harmony with the true wants of the people. The outgrowth of these agricultural colleges will be an intelligent class of farmers who will give to agriculture that prominence and influence in the nation which it so justly deserves.



THE GREAT INTERNATIONAL AGRICULTURAL SHOW, LONDON, 1879.

THE IMPORTANCE OF THE STUDY OF FUNGI.

THE lower forms of vegetation which have hitherto been grouped under the general name of fungi, are of much more immediate interest to men in ordinary avocations than is commonly supposed. There is hardly a man anywhere who is not more or less affected directly by these almost unknown organisms; and yet, curious as it may appear, there are but very few people who have any knowledge whatever of their structure, habits, modes of propagation, etc., etc. With regard to many of them, the crudest notions are held by people of considerable attainments—not a few supposing that fungi are related in some way to insects, if not forms

of them, while others regard them as mere excrescences, and still others as the results of a chemical action of some kind. I have frequently heard intelligent men pronounce the rust of wheat and other grain to be a kind of oxidation of the sap of the plants, analogous to the oxidation of iron in its common and familiar rusty state.

Now, if people would study these things a little, such crude notions would at once cease to have a place in their minds. Fungi are plants, and are as much entitled to a place in the vegetable kingdom as are oaks, maples, or other large plants. The greatest structural difference between a fungus and an oak tree is that in the former it is simple, while in the latter it is exceedingly complicated. The essentials of a plant are present, however, in the one case as in the other: in both, the individual plant cell is found; in both, there are organs of nutrition; in both, there are organs of reproduction. The mere fact of the greater simplicity of the fungus as compared with the oak, must not blind us to the many points in which the two are alike. And then, too, the simplicity of the fungus is only relative; the student of the lower forms of life is well acquainted with hundreds of undoubted plants which are as much simpler than ordinary fungi as these latter are simpler than the oak.

Now, it is sometimes said that the knowledge that fungi are true plants is of no account in enabling us to check their growth or prevent their working us injury. Such, however, is not the case, for it is clear that when we know that these organisms have definite times and modes of reproduction, we have gained a most important advantage in our fight with them. If the housewife knew that the mould which invades her pantry and cellar, produces at certain stages myriads of little reproductive bodies, analogous bodies, analogous to the seeds of higher plants, she could serve her pests just as the careful farmer serves the weeds in his fields; that is, she could see to it that no spores were allowed to develop and give rise to new mould plants. I can not emphasize this too forcibly: our treatment of fungi may, when we are sufficiently intelligent, be exactly like our treatment of weeds, for they are nothing more nor less than microscopic weeds.

The rusts and smuts which attack the farmer's crops are minute weeds of the worst type; they live at the expense of other plants by absorbing their sap and other fluids, and are thus true parasites. The plants have, however, definite modes of reproduction, and the educated eye can at once detect their reproductive organs. The skillful experimenter can even take the spores and, by sowing them, produce new rusts and smuts exactly like those he begins with.

In other fields, these low organisms are important. When we build our houses, barns, bridges, or other structures in which wood enters, we find that dry rot soon seriously injures the strength and durability of the beams and joists we have used. Now, dry rot is another plant of this group of the fungi, and like its brethren mentioned above, it has its definite mode of reproducing its kind. So, too, with the various mildews and moulds which too often trouble the dealers in cloths: all are microscopic plants; and these, like all other plants, may be prevented from growing by preventing the deposit of the spores or by guarding against the conditions which favor their growth.—*Prof Bessey, College Quarterly.*

THE ERUPTION OF MOUNT ETNA.

The present eruption of Etna seems to be even more serious than was at first supposed. The mountain has broken out at three different points, distant from each other twelve or fifteen miles. It may be said that there are three separate eruptions going on at the same time. The most serious of the openings are those between the Monte Frumento and Monte Nero, an equal distance between Randazzo and Linguaglossa. At this spot the land is more highly cultivated. The flow of lava here seems to be immense and ever increasing in bulk. Here once stood the Bridge of the Pisciaro, which carried the national road over the torrent of that name, as it descends from the mountain to the Alcantara River. This bridge—the lava, no doubt, availing itself of the bed of the water course—has been carried away by the avalanche of boiling lava, and the road is overflowed with lava for about 100 meters. The other two points of outbreak are—one between Bronte and Adernò, on the western slope; the other between Giarre and Aci Reale, on the southern. The former seems to send out a small quantity of lava, in the first instance threatening the town of Adernò, but now considerably lessened in force. The whole population in the neighborhood of Etna is in a state of panic; the awful roars of the mountain heard from all sides, the vomitings of lurid smoke, and the rain of ashes and cinders are not calculated to restore the confidence disturbed in the first instance by the shocks of earthquake, the precursors of this calamity. News by a recent dispatch from Messina says: "Renewed and frequent shocks of earthquake, attributed to the volcanic action of Mount Etna, have occurred in the neighborhood of Santa Venere and Guardia, causing serious damage. Several houses have fallen in, and others are in danger. The loss of life is considerable. Communication by road is interrupted." An earthquake of great violence occurred near Aci Reale, in the province of Catania. Immediately after the opening of the sitting of the Chamber, Deputy Romeo read a telegram to the House announcing that five villages had been almost wholly destroyed. Ten persons had been killed and several injured. We give an illustration of the scene presented by the great stream of lava crossing the road between Linguaglossa and Randazzo on the 11th of June last.—*Illustrated London News.*

THE RECENT ERUPTION OF ETNA.

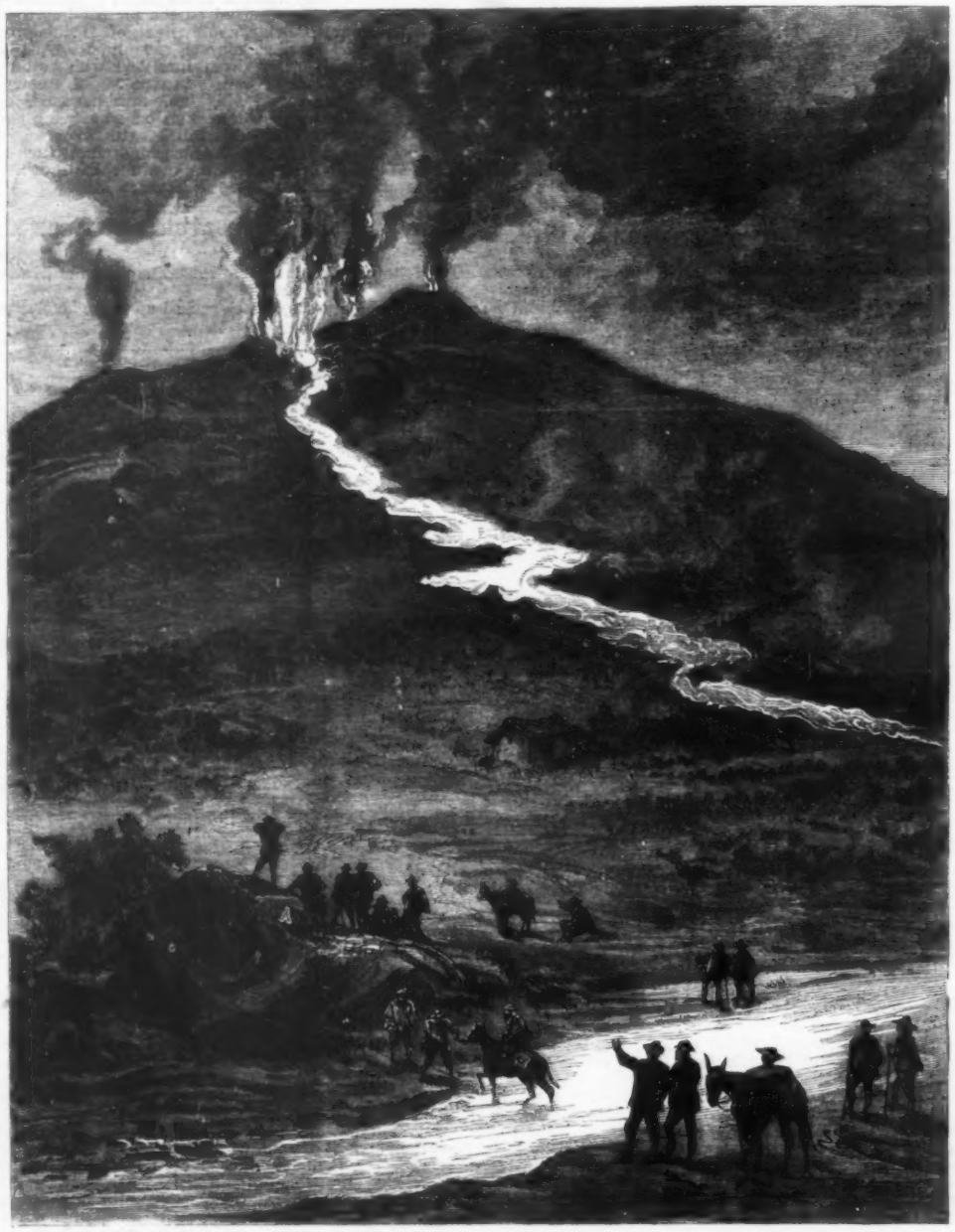
Prof. Silvestri has, with most commendable dispatch, just issued his report to the Italian Government on the recent eruption of Etna. It takes the form of a quarto pamphlet of nineteen pages, entitled "Sulla doppia Eruzione dell' Etna scoppiata il 26 Maggio, 1879," and it is accompanied by a capital map, showing the exact extent and dimensions of the lava streams.

At the end of our former article on the subject we mentioned certain anomalies in the accounts of the eruption already transmitted by telegram from Rome, and at the same time asserted that we must wait for the Government report before they could be explained. It is satisfactory to find that Prof. Silvestri has completely removed these anomalies, and has given a description of the eruption, which is so connected, reasonable, and precise that it leaves nothing to be desired.

Silvestri considers that preparations for this eruption have been continued since 1874, and that this is the fulfillment of the abortive attempt which was then made. On August 29, 1874, a rift opened on the northeast side of the mountain, between the great crater and Mojo, and thirty-five small eruptive mouths were formed along its course, together with one larger crateriform monticule, which discharged lava. But after seven hours of activity the dynamic forces suddenly decreased in intensity, and in two days' time nothing remained of the eruption save a few secondary manifestations. For a fortnight afterward, however, earthquakes occurred on the north side of the mountain, and the great rift remained open. Silvestri predicted that when the next eruption came this rift would prove the point of least resistance, and that the new lava would flow from it, or from craters raised along its course. This prediction has been completely verified.

The fissure of 1874 has extended itself—on the north-northeast toward Mojo, on the south-southwest toward Adernò. It is 10 kilometers (6·2 miles) in length, and passes through the great crater of Etna. On May 26 the south-western extremity discharged lava in the direction of Adernò, while simultaneously the northeastern extremity discharged lava in the direction of Mojo, thus presenting the curious anomaly of twin eruptions on opposite sides of the mountain. The craters on the south side of the mountain were situated near the base of Monte Frumento 2,650 meters (8,743 feet) above the sea. There were eight eruptive mouths, from 4 to 15 meters in diameter; seven of these were open, while over the eighth was raised a monticule. The lava did not flow directly toward Adernò, 13 kilometers distant, but toward a series of monticules formed during a previous eruption, and known as *Monti Grotta degli Archi*. It accumulated against the first of these mounds, and then divided into two branches, one of which commenced to flow toward Adernò, and the other toward Biancarilla, but the supply died out at the source, and the new streams solidified at a height of 2,000 meters, having flowed for a mile and a quarter as a stream 400 meters in breadth. This stream did but little damage; it did not penetrate into the cultivated region, and but in short distance into the woody region. It came into contact, however, with a bed of snow, part of which it converted into clouds of steam, while another portion was liquefied and rushed down the sides of the mountain in a foaming torrent, carrying with it a good deal of *débris*.

The outflow of lava ceased on the south side of the mountain, because the lava found a vent at a lower level on the north side. As the one decreased in activity the other increased. On May 28th Silvestri visited the scene of the northern eruption. A great column of smoke appeared about 20° east of north, while a shower of sand descended, producing the "sad leaden light" (*la luce triste plumbea*) observable during an eclipse. More than two pounds of this sand were collected in ten minutes in an inverted umbrella, and the north flanks of the mountain were soon covered with it. Silvestri ascended from Randazzo toward the new craters, and when at a height of about 2,000 meters, and near Monte Nero, he heard loud subterranean detonations, and perceived severe oscillations of the soil. Soon afterward he came upon the great rift, together with several smaller ones, converging toward the principal crater. In the immediate neighborhood of Monte Nero and Timpa Rossa three new craters were seen, from one of which dense clouds of white smoke issued, while the others emitted lava and showers of ashes and incandescent stones. Frequent flashes of lightning issued from the smoke. The stream of lava near its source emitted a very bright light which, when viewed by a direct vision spectroscope, gave the lines of hydrogen calcium, sodium, and potassium. The lava flowed downward at a rapid rate; the wood of Collebasso was destroyed, and by the evening of May 29 it had flowed 6¼ miles, destroying the bridge of Passo Pisciaro and crossing the postal road between Randazzo and Linguaglossa. On Sunday, the 31st, the stream was rapidly approaching Mojo; the inhabitants became frightened, and brought out the figure of their patron Saint Anthony, which was carried in procession to the edge of the stream, while the people fell on their knees and besought the Deity to save them from the impending danger. After the evening of June 1 the force of the eruption began somewhat to abate, and by the 6th inst. it was practically at an end. The lava stream ran nearly 7 miles from its source, and ultimately stopped 500 yards from the River Alcantara, and about half a mile from the village of Mojo. At its termination it is 23 feet in breadth and nearly 32 feet in height. The lava stream entered the bed of the Pisciaro torrent with a velocity of from 4 to 5 meters a second, which was reduced to 2 meters a minute in the lower valley of less inclination. In 76 hours the lava had flowed more than six miles from its source.



THE RECENT ERUPTION OF MT. ETNA: SHOWING THE GREAT STREAM OF LAVA.

Indications of a disturbed volcanic condition were manifest last October, when powerful shocks of earthquake were felt in the territory of Mineo, Palagonia, Vizzini, Scordia, Militello, and Caltagirone. Mineo was the center of disturbance, and here the shocks continued at intervals during the month of October. Loud subterranean noises were also heard at intervals. Two months later an eruption of mud and gas took place near Paternò, on the southern flanks of Etna. The mud was hot, salt, and petroleum bearing (*fango salato termale petroleifero*), and its ejectment continued for several months. Toward the end of December last the whole eastern seaboard was visited by a strong shock of earthquake; and soon afterward a great increase of smoke from the central crater of Etna showed that the dynamic activity of the mountain was unusually near the surface.

Even now we cannot regard the eruption as at an end. Ten days after the cessation of the flow of lava telegrams from Rome (dated June 17) announced that the neighborhood of Santa Venere and Guardia had been visited by repeated shocks of earthquake. A telegram on the following

day announced that "an earthquake of great violence" had occurred near Aci Reale, destroying five villages. There is evidently a great deal of volcanic energy still pent up not far from the surface, and we must fear that before long a further outburst will relieve the imprisoned Titanic forces.

—*G. F. Rodwell, in Nature.*

ASSYRIAN EXPLORATIONS.

MR. HORMUZD RASSAM has just returned to England, bringing with him the results of his second expedition to explore the mounds of the Tigro-Euphrates Valley. Although not furnishing any such grand discovery as that of the bronze gates from Balawat, the expedition has been an extremely successful one. With the exception of the explorations in Syria, and especially on the site of Carchemish, Mr. Rassam has followed the programme which was detailed in the *Times* of October 10, 1878. His explorations on the mounds of Nineveh have this time extended to a site hitherto untouched by former explorers—namely, the mound of the Nebby Yunus, or Tomb of Jonah. In this mound he was fortunately able to make some few explorations and to recover a number of inscribed fragments bearing inscriptions of the reigns of Esarhaddon and Sennacherib, as well as some statuettes in terra cotta, which exhibit a higher art than any before recovered. Explorations have been continued in both the palaces of Sennacherib and Assur-ban i-pal, and many hundreds of inscribed tablets have been recovered. On the mounds of Nimroud, the exploration of the Temple site, discovered by Mr. Rassam in his former expedition, was continued, and a number of fragments of tiles and several inscriptions were recovered. This temple, or rather temple area, is now found to have contained a number of altars as well as a systematically arranged series of seats. It would appear rather to have been a species of forum, where religious assemblies, councils, and other gatherings were held. Warned by the violent riots which attended his former explorations in the mound of Balawat, Mr. Rassam has carefully abstained from any attempt to continue the work there. His labors on sites which did not come within the scope of his former expeditions have been most fruitful considering the short period which he was able to devote to them. His explorations at Kileh Shergat, the site of the ancient city of Assur, the primitive capital of Assyria, have much enriched our knowledge of this site and furnished us with some valuable inscriptions of the early Assyrian Empire. Among these we may specially notice one brick written in a most archaic script. The discoveries which Mr. Rassam has been able to make on the mounds of Babylonia will be welcomed by all students of archæology, for hitherto the parent empire has been much neglected in favor of the northern offshoot, the Assyrian Empire. Mr. Rassam was able, after a considerable amount of opposition by the brick merchants, who dreaded his presence as a menace to their vandalism, to carry out a series of explorations on most of the mounds. From the examination of the ruins buried beneath the Mugelibè, Mr. Rassam has been able to ascertain the site of the edifice from which have come the series of banking and commercial tablets known as the Egibi tablets. From the relation of this edifice to the king's palace, it standing on the northeast side among a number of small buildings, evidently the royal offices, it is now clear that the theory advanced by Mr. Boscawen, that the traders were also the keepers of the king's treasury and the revenue officers of the Kings of Babylon, receives a strong confirmation. Hitherto, owing to the irregularity which has characterized the system of digging among the mounds of Babylon, no traces of any regular edifice have been found Mr. Rassam, however, managed to infuse some species of order among the brick-hunters, and the result was the discovery of several halls and rooms. In a mound called Jubjuba, the Jumjuma of Mr. Rich's memoir, he discovered the remains of a large hall of most rich construction. Painted bricks, rich Indian woods and enameled tiles, all indicated the richness of the edifice. His excavations in the Birs Nimroud have brought to light the remains of edifices and a number of inscriptions. A most interesting discovery in connection with this ruin has resulted from the examination of the site by Mr. Rassam—namely, that its destruction was due, not to fire or the vengeance of an enemy, but to a volcanic eruption which has split the whole edifice in twain and vitrified all the brickwork with which the lava and flame came in contact. The exploration of Babylon has too long been neglected, and it is to be hoped that the short but fruitful visit of Mr. Rassam will tend to direct attention to the site. We are glad to note that Mr. Rassam carried out the roving commission which we indicated in our notice of October 10, 1878, and exercised his authority on the itinerant explorers from Baghdad. He paid a visit to the mound of Tel Ho, and examined and copied the inscription on the black basalt statue which was there. He has also obtained a number of inscribed tablets from this site, and among them are several of those interesting examples of Babylonian cunning, the commercial deeds in duplicate, the one copy forming an envelope to the other. From this site he also obtained a number of very curious inscribed coins, with legends of early monarchs. During his visit to the city of Baghdad, he obtained by purchase a number of inscriptions, mostly of the contract or commercial class. As Mr. Rassam has been only a few days in England, and many of his cases have still to be forwarded, we cannot as yet fully learn the results of this expedition, but we have every reason to believe that students of both the philology and art of the Assyrian and Babylonian Empires will find much of great importance to aid them in all their researches.—*London Times.*

[Continued from Supplement 188.]

THE BEGINNINGS OF LIFE.—II.

RADIOLARIANS AND FORAMINIFERS.

THE illustrious micrographer, Ehrenberg, while one day examining the muddy deposits which form in the mineral springs of Franzenbad and Carlsbad, in Germany, was not a little astonished to find them composed almost entirely of silicious corpuscles, often of great elegance, and always of a well defined form, which could have been produced only by living beings. Pursuing his researches in analogous deposits, he discovered that a large number of them were made up of these same elements. Soon, even large geological formations, those of chalk, furnished him with the shells of microscopic beings in such abundance that the mass of other fossils was insignificant in comparison. Entire islands—Barbadoes, for example—are, so to speak, only the gigantic ossuaries of a world as marvelous for the minuteness of its inhabitants as for their infinite variety and prodigious numbers. An ounce of the sand of the port of Gaeta contains no less than a million and a half of these invisible skeletons, which, however, may be accumulated in sufficient quantities to form mountains.

These skeletons, of a delicacy of structure that defies the ability of artists to delineate them, of a wealth of form that surpasses all that the most brilliant imagination can conceive of, belong to two very distinct types. In the first of these the shell is sometimes of extraordinary complexity and singular beauty. It is generally perforated by innumerable minute orifices (*foramina*), through which the animal protrudes its myriad of glairy, thread-like arms. The majority are compound, resembling chambered shells, formed by a process of budding, each new individual being added so as to make a straight series, a spiral, or a flat coil. As a rule the many-chambered species have calcareous perforated

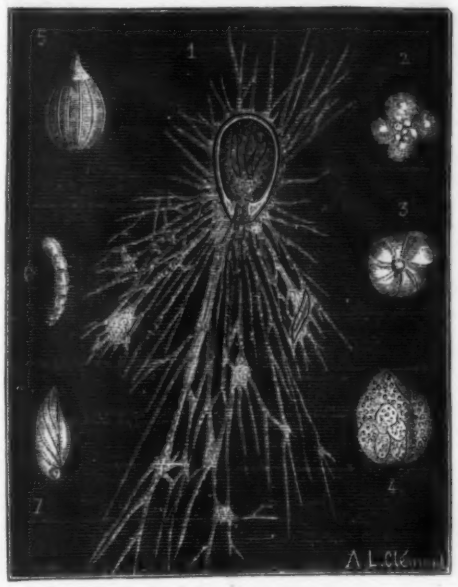


FIG. 1.—VARIOUS FORAMINIFERA.

1. *Gromia oviformis*, Duj. 2. *Globigerina bulloides*, D'Orbigny. 3. *Anomalina hemisphærica*, Terquem. 4. *Rosalina anomala*, Terquem. 5. *Lagenulina costata*, Williamson. 6. *Dentalina punctata*, D'Orbigny. 7. *Cristellaria triangularis*, Tarquem.

shells; and the one-chambered have an imperforated membranous, porcelanous, or arenaceous envelope (Figs. 1 and 2). In the other type the shell is formed of latticed spheres, enclosed one within another, or long radiating needles united at one of their extremities, free, or connected with each other by a beautiful stony lace-work; sometimes again the shell is reduced to small bodies in the shape of anchors and hooks. In all cases the shell is silicious (Figs. 3 and 4)

The calcareous-shell animals of the first type are called foraminifera; and those of the second are designated as radiolaria or polycystina.

In view of the complicated nature of their skeletons we might be led to think that the animals themselves, in spite of their minuteness, were of a complicated structure. Indeed, some distinguished naturalists have held such an idea. D'Orbigny, for instance, struck by the resemblance that the microscopic shells of the Foraminifers present to those of certain mollusks, such as the Nautilus and Spirula, and the fossil ammonites, believed that they also were mollusks; and he was confirmed in this opinion by the fact that when the animals are alive the openings in their shells

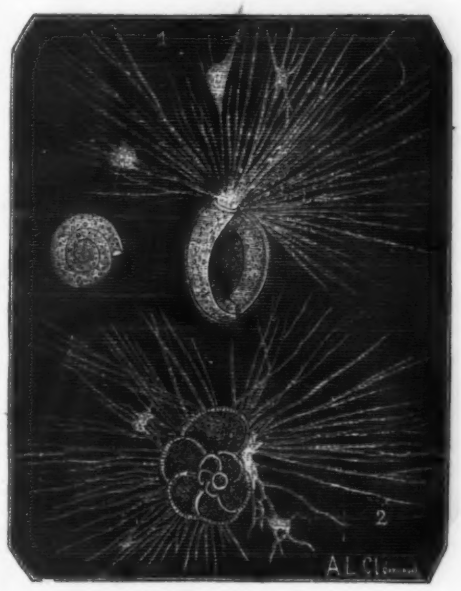


FIG. 2.—VARIOUS FORAMINIFERA.

1. *Miliola tenera*, Max Schultze. 2. *Rotalia Veneta*, Max Schultze. 3. *Cornuspira planorbis*, Max Schultze.

serve as passages for a multitude of arms, presenting a vague resemblance to those of a poulpe. However, a careful examination with the aid of the microscope quickly leads to an entirely different opinion. The arms, which are often of an orange color, and which the animal protrudes through the orifices in its shell, in nowise show the fixidity of form that characterizes those of the poulpes; not only do they lengthen and shorten at every moment, but they also become divided in a thousand ways, their ramifications becoming amalgamated when they come in contact, thus forming irregular net-works the meshes of which are continually enlarging and contracting. Nor are such amalgamations merely seeming ones; they are real, as may be seen when these arms are carefully examined.

What can this substance be, then, that is so apt to ramify to such a degree, and which so readily amalgamates with its own substance; which is contractile and yet homogeneous, living and yet like a drop of mucilage without structure, and which can, according to circumstances, mass itself up into a heap or stretch itself out into long filaments? This substance we know, we have already seen it forming all of the moners and those beings most closely allied to them. It is protoplasm. The establishment of this fact we owe to the illustrious Dujardin. It was the foraminifers and radiolarians that furnished him the first idea of his theory of sarcode, of which we have already spoken. He it was who demonstrated that the supposed arms of these beings are only prolongations of sarcode. The analogous prolongations of the moners we have already designated as pseudopodia. Here the pseudopodia ramify like the fibers of a plant root; and hence the name rhizopods (from *rhiza*, a root, and *pous*, a foot). The pseudopodia of foraminifers and radiolarians have the same properties exactly as those of the moners and amœbas. They paralyze the small crustaceans and infusoria that come near them, by simple contact, seize them, envelop them in their mucilaginous network, dissolve them, and incorporate them into their own substance.

There is no doubt then that we have here a true protoplasmic substance. In the sarcodic mass of a foraminifer, the most minute researches, especially the very recent ones of Hertwig, have not been able to detect anything else than a nucleus such as that of the amœbas or actinophrys; and this nucleus changes its position according as the number of its cells increases.

The structure of the radiolarians is a little more complicated. In the center of their mass, which does not exceed in size the head of a pin, the microscope shows a membranous capsule, the contents of which are segmented into more or less opaque polyhedral masses, immersed in the protoplasm.

The protoplasm contained in the capsule and that by which it is enveloped are continuous. The silicious spicules and needles often traverse its walls and unite in its center; but the capsule has no direct relation with the skeleton properly so called. In the sarcodic mass we also find yellow refracting corpuscles, which seem to be true cells, and which also are independent of the skeleton. In several types of little larger size there exist several central capsules. These forms must be considered as the result of the union of several ordinary individuals that have united their protoplasm in common and only remain distinct by reason of their central capsule. They are to the radiolarians almost what the Myxodyctia are to the Protomyxæ—they are compound Radiolarians. It is probable that there are also compound foraminifers, and perhaps we ought to consider each cell of one of these animals as a distinct individual, so that the only simple foraminifers would be the unilocular ones, as Lagena, in the shape of a bottle; Vertebralina, in the form of a rod, or Cornuspira, in the shape of a spiral. The multicellular foraminifers would be compound species, true colonies of unilocular foraminifers. In fact, Nodosaria, Dentalina, Cristellaria, Frondicularia, Flabellina, etc., represented in Figs. 1 and 2, accompanying this article, seem to be only differently grouped colonies of Lagena, and we find among them all sorts of intermediate forms. On the other hand, there likewise exist all possible intermediate forms between the complicated ones, such as spiroculina or quinqueloculina, and the simpler ones, such as biloculina and miliolina. These, then, are forms which appear to have been derived one from another, by the gradual adjunction of new individuals to the primitive ones, according to laws, however, that are very variable. However this may be, we find ourselves here in the presence of a new fact of high importance. The shells of rhizopods, so varied and so regular in form, can have been produced only by that living, amorphous, homogeneous, semifluid substance that we call sarcode or protoplasm. In spite of the geometrical appearance of the skeleton of some Radiolarians, it is easy to assure ourselves that these shells have nothing to do with crystallography. Now, since the living substance under consideration has no form, how has it been able to give form to the solid matters which are deposited in its mass? Notwithstanding the researches made by Harting with a view to explaining it, we may say that it still remains an impenetrable mystery to us, and one which shows us, perhaps better than anything else, what a profound difference exists between protoplasm and the ordinary chemical media. Here again appears the diversity of fundamental living substances. How is it that protoplasm attracts to itself, now calcareous salts, and now silica, and deposits them regularly in its substance? How is it that it confines itself at other times to enveloping itself in a simple membrane, which remains smooth, as in Lagynis, Gromia, and Lieberkuhnia, or glues foreign bodies to its surface, as happens in Lituola? We can only state the facts, and investigate. Explanation we have none to give.

If we admit that the living primitive substance was unique and without distinct individuality, as we usually conceive of bathybius or protobathybius, it is evident that, all its parts being identical with each other, constantly increasing, and amalgamating on coming in contact with each other, this substance must in the end have formed an enormous mass, continuous and homogeneous throughout its whole extent. We cannot conceive how this mass can have been nourished, since there existed no organic matters besides itself; we cannot conceive how its different parts have been able to become at length individualized, and consequently how the faculty of reproduction has arisen. Finally, we cannot conceive how the individuals, all alike, from first formation have been able to acquire different properties, and, especially, how these properties can have been preserved, since the assembling of different individuals in the same place, instead of giving rise among them to a "struggle for existence" and "selection," must have produced their fusion, and consequently, a return to the primitive type.

The supposition that at first there may have been formed a small number of primitive living substances does not resolve the problem either, since for each one of them we may repeat the preceding reasoning, and thus be led to believe that the primitive beings must have made their appearance with a determinate individuality, with properties particular to each individual, and a power of special evolution, the exterior circumstances of which have afterwards been able to determine the effects. So, the supposed simple elements of chemistry have appeared at the first onset with their particular properties, and their special affinities, by means of which, under the influence of various circum-

stances, have been formed the innumerable compounds that we know to-day. The present organisms may have come from primitive living substances, as chemical compounds have come from bodies reputed simple. Only the stability of the latter allows us to isolate them, while living substances seem to have irrevocably lost their initial properties by very reason of their mobility and their faculty of perpetuating themselves while preserving their acquired characters.

Moreover, once the individuality acquired, protoplasmic beings in an isolated state can only assume very small dimensions; for, as soon as these dimensions are exceeded, the individual undergoes a division. Hence we cannot conceive how animals or plants of large stature can have proceeded from these protoplasmic beings, except by admitting that a multitude of the latter have become grouped together to form such organisms. The theory of descent leads us then to consider the superior organisms as true colonies of protoplasmic beings. We shall follow up this view of the case, and show what there is in it.

The myxodyctia, the foraminifers, and the compound radiolarians exhibit to us the first of these colonies.

The mode of reproduction of the foraminifers is not very well known; but, thanks to the researches of Hertwig, we know more about the radiolarians. At a certain moment the pseudopodia and the protoplasm surrounding the central capsule gradually disappear; the contents of the latter become divided into a multitude of small spheroidal bodies, which, on the rupture of the capsule, appear under the form of globules provided with a movable, constantly agitated filament that serves as a locomotive apparatus. Here again we find the reproductive body that we have already met with in the protomyxæ, the myastra, the protomonas, and other moners. Only this body is here provided with a nucleus, and even sometimes contains a mineral concretion of crystalline appearance (Fig. 4, Nos. 3 and 4).

This persistence of form of the reproductive bodies is important; we shall have to describe it anew; we shall see it even becoming fixed and producing truly independent organisms, the flagelliform infusoria, which in their turn originate more important types.

To sum up, the reproduction of rhizopods does not differ from a simple division of the parent into a variable number of new individuals. This is going to give us the explanation of a most remarkable phenomenon by which all naturalists who have studied these beings have been struck. The foraminifers are innumerable, and this statement is as applicable to the forms that they assume, and which we might be tempted to call specific, as it is to the individuals themselves.

Some eminent naturalists have given considerable time to the study of these forms. William Carpenter, of England, has endeavored to classify the living species, and has published a large quarto volume on the subject, modestly entitled "Introduction to the Study of the Foraminifera." In France, M. Terquem has published a whole series of splendid memoirs on the fossil forms. Both arrive at the conclusion that it is impossible to fix a limit to the variation of the species, since they pass into each other through gradual transitions. So Carpenter does not hesitate to say that there are no species among the foraminifers, but series of forms only, all more or less connected with a very great number of types, and the latter themselves connected with each other in many different ways.

Very recently, Prof. Haeckel has had occasion to examine a rich collection of radiolarians gathered by the Challenger during her dredging expedition. *A priori* he ordered a hundred quarto plates to figure the forms that he believed that he had recognized as distinct. A profounder examination showed him that these hundred plates would just allow him to figure the principal types. There existed among these types intermediate forms in infinite number; and no character allowed him to distribute them into species in spite of the apparent regularity of their solid parts, which would seem to give a hold on precise characteristics. Species, then, do not exist, either, among the radiolarians. To obtain an estimate of these strange conclusions, it will suffice, first, to compare the conditions of reproduction among the inferior beings under consideration with those of more elevated beings belonging to the animal and vegetable kingdoms. In the latter case reproduction requires in general the concurrence of two different individuals, or, at the very least, of the entirely different elements of a same individual. In the act of fecundation the personal character of the individuals tend to become neutralized, and the characters that are common to them—the specific characters—tend to suppress the others. So the species is maintained with characters that are almost constant, and whose limit of variation is yet to be determined.

But sexual generation does not exclude another mode of reproduction among a large number of animals and the majority of plants, and in which any part whatever detached from an individual is fitted to constitute a new individual. In other words, vegetables, for example, are reproduced not only by seeds, but also by buds, layers, etc.

No one is ignorant of the fact that, in the latter case, the young exhibit not only all the specific characters, but also all the essentially personal ones of the individual from whence they have been derived. It is in this way that gardeners preserve the innumerable varieties that they have succeeded in obtaining, either from ornamental plants or from fruit trees.

All that we know at present authorizes us to think that sexual generation does not exist among rhizopods. With them, then, reproduction is only a true budding, and consequently all the individual variations are preserved and accumulate with time, ever modifying the primordial forms, diversifying the forms issuing from the same parent, approximating other forms of different origin, and thus establishing thousands of accidental connections between one type and another. Hereditary influence, which, in the sexual mode of generation, tends to maintain the constancy of forms, seems here to put itself at the service of the modifying influence of the exterior actions whose effect it has contributed to maintain. A species, then, cannot become fixed. Theoretically, it could not exist in beings deprived of the power of sexual generation; and the facts, as we have just seen, are in perfect accordance with theory. On the other hand, the variations that the properties of protoplasm may experience under the action of external circumstances could not here be maintained in a determinate direction, as may happen in superior organisms among which the struggle for existence is active, natural selection consequently vigorous, and improvement rapid. The ornamentation of the shell of a foraminifer, the form of the spicules of a radiolarian, their very arrangement, could not insure much of an advantage to the protoplasmic mass which secretes them. All these masses are nearly equivalent as regards vital activity. We see in them no reason for progress. Their forms, in spite of their inconstancy, are always turning around them in the same circle. The original types are preserved as well as the varieties derived from them; and this is why analogous forms of rhizopods are found at once among the most ancient fossils and in the present fauna. But since we find here none of the conditions to which Darwin attributes the formation of elevated species, how are we to explain, what moreover is necessary in the theory of evolution, that these species are derived from the simple forms of which we have spoken, when these forms seem to be doomed to an eternal inferiority?

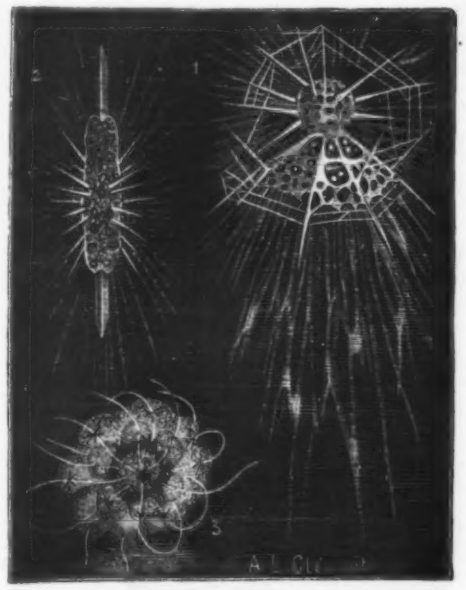


FIG. 3.—RADIOLARIA.

1. *Arachnocorys circumtexta*, Haeckel. 2. *Amphilonche heteracanta*, Haeckel. 3. *Acanthometra elastica*, Haeckel.

The egg of existing animals, even of the highest, is simpler than the majority of rhizopods. It, too, is only a small mass of protoplasm, inclosed in a delicate membrane, and containing a nucleus and a nucleolus. This egg, however, possesses a faculty of evolution, the nature of which escapes us, which our senses do not permit us to define, and which leads it through thousands of transformations to a precise and determined end. Must it be admitted that at the moment at which they have had birth the first protoplasms have likewise each received a special faculty of evolution, which has permitted some to produce the most highly organized living beings under the stimulating action of external agents, while others have been able to raise themselves only slightly above their primitive condition? Perhaps so.

So some of our simple bodies—the precious metals for example—have furnished from the beginning of ages a small number of compounds only, while others, like carbon, hydrogen, and oxygen, have assisted in thousands of metamorphoses, and have furnished an incalculable number of combinations as complex as varied.

So, we must not disguise it, we have been obliged to have recourse to hypothesis to explain the origin of the simplest organized beings, and it is also a hypothesis to attribute to these beings the honor of having been the root of the animal

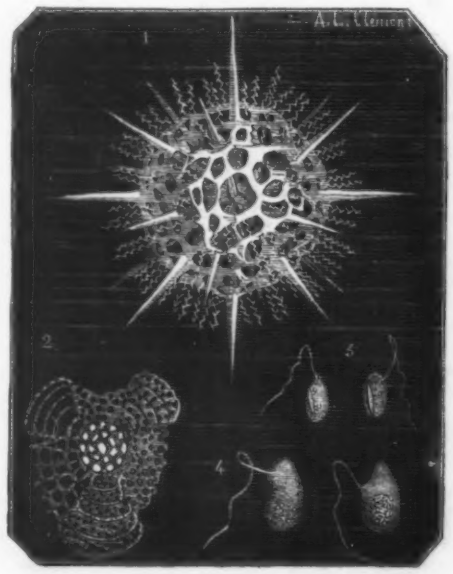


FIG. 4.—RADIOLARIA.

1. *Doratospis polyamystra*. Haeckel. 2. *Ouchitonia Beckmanni*, Haeckel. 3. Spiculiferous spores of *Collozoum*. 4. Spineless spores of *Collozoum*.

and vegetable kingdoms. There will be reasons for allowing these hypotheses to stand, if they will permit us to group a considerable number of facts, by the aid of which, if possible, we may explain the formation of the highest organisms. This is what we shall examine; but first a few questions suggest themselves: Is there any shadow of proof that animals and plants are derived from beings analogous to those whose history we have sketched? Can we descend by gradual transitions from the superior animals and plants to protoplasmic beings? Do there exist beings intermediate between the two great organic kingdoms? This we propose to examine in a subsequent article.

SUSPENDED ANIMATION.

THE nitrite of amyl being a powerful agent in quickening the heart beat, a few drops of this drug have a powerful influence in restoring the functions of the heart in cases of drowning, hanging, or fainting. It is suggested, therefore, that it should always be used whenever attempts are being made to restore to life in an individual apparently dead, or when it is desirable to settle the question whether a person is really dead or not. The dreadful thought of being buried alive has haunted the human race since its earliest days, and the discovery of some means by which this risk could be, if not evaded, at least greatly diminished, would prove an ineffable boon to mankind. Dr. T. Lauder Brunton, to whom we have referred this suggestion, considers it to be a good one. He adds that in ascertaining death the nitrite of amyl might be used along with the cord test, of tying a cord around the finger. If the circulation has entirely stopped, the part beyond the ligature never becomes any thicker; but if circulation continue, however slowly, the finger tip beyond the ligature will sooner or later begin to swell.—*Brit. Med. Jour.*

SUCCESSFUL TRANSFUSION OF HUMAN BLOOD.

By WILLIAM MACEWEN, M.D., Surgeon and Lecturer on Clinical Surgery, Royal Infirmary, Glasgow.

THE following case of transfusion of human blood is worthy of record on account of the antiseptic precautions which were adopted and the complete success of the operation:

The patient was a man, twenty-three years of age, on whom lithotomy was performed for the removal of a large spiked oxalate-of-lime calculus. There was little bleeding as an immediate sequent of the operation, and it was completely arrested before he left the table. Half an hour after having been put to bed the house surgeon found him to be very comfortable and in a good general state; there was then only slight staining on the sheet under the pelvis. Two hours and a half after he was found to be in a state of complete depletion, from a profuse secondary hemorrhage which had ensued. The wound was at once plugged. Notwithstanding every attempt to resuscitate him by stimulating drinks, enemata, etc., it was evident at the end of three-quarters of an hour that ground was being fast lost, and it was clear to all present that, if his life was to be saved, something more radical was necessary. Transfusion of blood was proposed. A patient who suffered from injury to the right great toe, and who otherwise was strong and healthy, after being apprised of the slight risk he ran in giving a portion of his blood, freely offered it to his fellow.

The lithotomy patient was then in the following state: He was semi-insensible, could not speak, pulse at the wrist imperceptible, surface of the body blanched and bedewed with a cold perspiration, the lips cream-colored, and the conjunctival vessels no longer visible. Occasionally he gave a restless, feeble toss, accompanied by a deep inspiration.

An attempt to find one of the large veins on the right arm being unsuccessful, the median cephalic of the left was chosen and half an inch of its length exposed. An assistant was desired to place the finger of one hand to the distal side of the exposed vein, and to maintain pressure on that part throughout the operation, so as to prevent loss of blood; and with a finger of the other hand, placed on the proximal side about half an inch above the part selected for opening the vessel, he was to occlude the vein when required. The arm was held well up, so as to empty it of any blood which it might contain. It was also maintained considerably above the level of the patient's body, for three reasons: First, to facilitate the flow of the transfused blood into the trunk; secondly, to prevent the entrance of air into the body, as the syringe would, with the arm in this position, be necessarily held perpendicularly, with the nozzle downward, and all contained air would remain at the top of the instrument; and, thirdly, to enable any air to escape which might be in the space intervening between the opening in the vein and the occluding finger of the assistant on the proximal side. The vein was then opened. Then phlebotomy was performed on the healthy man, the blood being received into a small warm carbolized vessel, from which it was at once drawn into a warm carbolized three-ounce syringe, having a narrow nozzle. When full it was inverted and the piston pressed, so as to expel any air, and the nozzle was then introduced into the vein. A quantity of blood was first injected into the space in the vein, between the occluding finger on the proximal side and the opening in the vein itself. When this was done the pressure on the proximal side was removed, and the contents of the syringe were slowly injected, until only a couple of drachms remained. The pressure of the assistant's finger was again applied and the syringe removed. It was then washed in 1 to 80 carbolized watery solution, recharged, and the blood introduced as before. The tin into which the blood flowed was kept free from clot, and several times a fresh cup was substituted. The arm from which the blood was drawn, as well as that into which it was injected, were kept constantly under the spray, and the blood itself, from the time it left the one arm until it was injected into the other, was either exposed to the carbolized spray or in contact with carbolized instruments; so that the whole transfusion was thoroughly antiseptic.

With the exception of the transfusion being performed antiseptically, the other details of the operation were nearly the same as those adopted by Mr. Lister in a case in which he performed transfusion, while I acted as one of the house surgeons in the Royal Infirmary. That case was reported by me in the *Glasgow Medical Journal* for November, 1869.

Just before the transfusion was begun several of the house surgeons hinted that the patient had "slipped away." His heart, however, was heard to respond, and the blood was injected. Shortly after the transfusion the gentleman who had his finger over the radial said that, from being imperceptible, it had returned gradually, and had increased until it was distinctly felt. Half an hour after the face had assumed a slight redness, and beat began to be restored to the surface of the body. There were no rigors after the transfusion. Without entering into further detail, it may be said that he slowly but perfectly recovered, and is now a strong, healthy man. He was shown at the Pathological and Clinical Society nine months after the operation, and is still quite well and at work.—*Lancet.*